The Impact of Professional Development on Mathematics Teachers' Beliefs and Practices

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Abstract

This thesis describes the analysis of the implementation of a professional development programme for secondary mathematics teachers in England. The research used a mixed-methods multiple case study design with three secondary schools.

The aim of the study was to understand mathematics teachers' professional learning in the context of this professional development programme. However, through *analytic generalisation*, i.e. generalising to theory, these findings may have broader application to understanding teachers' professional learning.

Social learning theory was used as a framework for explaining professional learning, within this are two components, *observational learning* and *self-efficacy*. Teachers learn to teach through observing behaviours and models of teaching; they implement the approaches that they are confident will be effective in their classroom—that they are *self-efficacious* about.

I show how this explains the prevalence of traditional teacher-centred teaching in secondary mathematics and how, through observing models of alternate approaches in PD, and through developing self-efficacy in that approach, teachers can implement new approaches in their teaching.

In this research, I show that the PD—designed to support teachers in teaching to develop students' problem solving skills—had an effect on teachers' practices: their teaching became more student-centred. It also had a positive effect on teacher self-efficacy in the suggested approach.

In the qualitative analysis of multiple individual cases, I explore how observational learning processes work, in the context of the PD, and the mechanisms by which teacher self-efficacy is developed.

However, a contextual analysis demonstrates that the extent to which the ideas in the PD are implemented and sustained are influenced by context—at a national level and within the school. High-stakes accountability and lack of integration of PD initiatives into school strategic plans lead to PD efforts not being sustained.

The main contribution of this thesis is in bringing a new theoretical approach to the field of mathematics teachers' professional development and professional learning, that of *social learning theory*: one that has the potential to improve the design and evaluation of professional development and teacher education in the future.

Abbreviations and acronyms

ATM	Association of Teachers of Mathematics
BSRLM	British Society for Research into Learning Mathematics
Cert. Ed	Certificate of Education
CPD	Continuing Professional Development
CRME	Centre for Research in Mathematics Education, University of Nottingham
DBR	Design-based research
DCSF	Department for Children, Schools and Families (2007 to 2010)
DES	Department for Education and Science (1964 to 1992)
DfE	Department for Education (1992 to 1995 and 2010 to present)
DfEE	Department for Education and Employment (1995 to 2001)
DfES	Department for Education and Skills (2001 to 2007)
EAL	English as an additional language
GCSE	General Certificate of Secondary Education
GTP	Graduate Teaching Programme
HMI	Her Majesty's Inspectorate of Schools
ICME	International Congress on Mathematics Education
ICMI	International Commission on Mathematics Instruction
IGPME	International Group for the Psychology of Mathematics Education
INSET	In-service training
JMC	Joint Mathematical Council
LA	Local authorities
LEA	Local education authorities
MA	Mathematical Association
M	Mean
Mdn	Median

MKT	Mathematics knowledge for teaching
NASUWT	National Association of Schoolmasters/ Union of Women Teachers (UK teaching union)
NCTM	National Council of Teachers of Mathematics (USA)
NCTL	National College of Teaching and Leadership
NCETM	National Centre for Excellence in Teaching Mathematics (England)
NQT	Newly Qualified Teacher
NUT	National Union of Teachers (UK teaching union)
OFSTED	Office for Standards in Education
PCK	Pedagogic content knowledge
PD	Professional development
PGCE	Postgraduate Certificate of Education
PLC	Professional Learning Community
PME	Psychology of Mathematics Education
PRIMAS	Promoting Inquiry-based learning in Mathematics and Science
QCA	Qualifications and Curriculum Authority
QCDA	Qualifications and Curriculum Development Agency
QTS	Qualified Teacher Status
RECME	Researching Effective CPD in Mathematics Education
SCK	Subject content knowledge
SCP	Shell Centre Publications Limited
SE	Standard Error of the Mean
SEN	Special educational need
STEM	Science, technology, engineering and mathematics
TA	Teaching Agency (2011 to 2013)
TA	Teaching Assistant
TDA	Training and Development Agency (2006 to 2011)
TIMSS	Trends in International Mathematics and Science Study and Mathematics Education
TLR	Teaching and Learning responsibility
TTA	Teacher Training Agency (1994 to 2006)
UoN	University of Nottingham

To all those who have contributed to me becoming a teacher and educator.

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Chapter 1

Introduction

The focus of this research is on mathematics teachers' professional development. Professional development that supports teachers in teaching to develop student problem-solving skills in secondary mathematics. This interest arose out of my own teaching experience. However, as I began my research into this issue, I was soon to realise that this issue is not, by any means, something we have been puzzling over exclusively in recent years. I was reassured to find that the problem I was to research was at least 450 years old. The following is an extract from *The Ground of The Artes* (1543) by Robert Recorde (1512–1558).

> *Master.* So may you if you have marked what I have taught you. But because thys thynge (as all other) must be learned by often practice, I wil propounde here ii examples to you, whiche if you often doo practice, you shall be rype and perfect to subtract any other summe lightly ...
>
> *Scholar.* Sir I thanke you, but I thynke I might the better doo it, if you show me the workinge of it.
>
> *M.* Yea but you must prove yourself to do som thynges that you were never taught, or els you shall not be able to doo any more than you were taught, and were rather to learne by rote (as they cal it) than by reason (*The Ground of Artes*, sig. F, i, v, cited in, Howson, 1982, p. 20).

What Recorde considered here is, on one hand, the teaching of methods and procedures, and the other, independent problem solving. And, as I say, this has been of personal and professional interest to me. In 2001, I trained to be a mathematics teacher at the University of Sheffield. I soon became interested in the teaching of problem solving. That is, how students develop transferable skills in being able to solve unfamiliar problems, from the real world or within mathematics: where the method to use is not immediately obvious or that there are alternative approaches that can be used. In this, I have adapted a definition developed by Schoenfeld (1985) who, building on the work of Pólya, (1990) suggested that problem solving involves students working with unfamiliar and complex problems.

Problem solving, according to Schoenfeld, is an activity involving a task where it is not obvious which technique or method to use (Schoenfeld, 1992). Moreover, a mathematical problem is "... a task (a) in which the student is interested and engaged and for which he wishes to obtain a resolution; and (b) for which the student does not have a readily accessible means by which to achieve that resolution" (Schoenfeld, 1989, pp. 87–88). This, in fact, is the definition I use throughout this thesis.

The challenge for me, as a teacher, was in creating a classroom environment in which I could develop students' problem-solving skills. In the schools that I taught, teaching was consistent with the observations of the Office for Standards in Education (OfSTED), they concluded that mathematics teaching generally involves a teacher demonstrating a mathematical procedure then students are expected to become proficient by applying that method to a series of routine problems. This approach to teaching has been identified as prevalent in mathematics lessons (OfSTED, 2008, 2012).

I also became aware, later in my career as a head of mathematics, how difficult it was to encourage teachers to do something other than the traditional approach. The issue is that traditional teacher-centred approaches are time-served and effective in managing classrooms and behaviours and, at least when I was a teacher, I was not exactly sure what was the most effective way of teaching mathematics to foster students' problem-solving ability.

This thesis is not about the second issue. I do not look into how best to teach problem solving. I will use what can be considered a rather unsatisfactory and rather generic descriptor of pedagogy for teaching problem solving. However, this will not diminish or detract from the main aim of this research. That is, understanding how teachers might be supported, through professional development, to develop student problem-solving skills. The generic characterization for pedagogy and practice to facilitate the development of student problem-solving skills is *student-centred problem solving*. This is a contrast to traditional teacher-centred approaches which involve the teaching of methods and students learning through practising with routine problems. The student-centred approach is characterized by students working on open-ended tasks, as described by Schoenfeld above, either collaboratively or individually. The 'student-centredness' is a shift in authority over the methods and is to allow students the experience of problem solving in order to develop their problem-solving skills.

The problem is that effective pedagogy for teaching problem solving is under-researched. This why I say my definitions and descriptors are rather generic. However, in this respect I am saved, to some degree. As this research uses professional development materials in which the designers have proposed pedagogy for teaching problem solving. My aim is not assess the efficacy of their vision of pedagogy but to consider how teachers might implement the approach and what the problems and constraints are.

This leads to a third problem, as I present in Chapter 3, theory in professional development is not well developed. Thus, the starting point

for this research was based on three assumptions:

1. Secondary mathematics teaching is predominantly and prevalently traditional and teacher-centred in England.

2. Teaching practices and approaches are difficult to change.

3. There is no overarching theory for mathematics teachers' professional learning.

I examine and justify these in the Chapter 3. In this research, I investigated *how* teaching changes, what is needed, what the constraints are and what the processes are.

In order to investigate these I needed the opportunity, I needed access to schools and professional development, and resources to carry out this research. It was therefore opportune that the Shell Centre for Mathematics Education at the University of Nottingham was also interested in these issues and was in a position to fund this research.

The Shell Centre had designed professional development materials to help teachers in teaching problem solving. They were interested in finding out how their materials worked in schools. I take a closer look at the *Bowland Professional Development* materials in the next chapter.

Our shared aim was to closely observe teachers using the professional development materials over a period of time, and attempt to understand how the professional development influenced their teaching and also identify the factors that impact on the effectiveness of the professional development. From this, the Shell Centre wanted to know how they could develop future professional development materials.

Before describing the structure of this thesis, I provide some definitions. Professional development is a broad term, Czerniawski (2013) described it as "portmanteau term" and as a "strategic shorthand" (p. 384). Craft (2000) suggested that it covers a broad range of activities that contributes to the learning of teachers who have completed their initial training. Professional development is the means by which teachers develop their skills in and knowledge of teaching and learning, or "those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they might in turn, improve the learning of students" (Guskey, 2000, p. 16). Day (1999) provided a similar but expanded definition:

> Professional development consists of all natural learning experiences and those continuous and planned activities which are intended to be of direct or indirect benefit to the individual, group or school and which contribute, through these, to the quality of education in the classroom. It is the process by which, alone and with others, teachers review, renew and extend their commitment as change agents to the moral purposes of teaching;

> and by which they acquire and develop critically the knowledge, skills and emotional intelligence essential to good professional thinking planning and practice with children, young people and colleagues through each phase of their teaching lives (Day, 1999, p. 4).

There are multiple related terms including, for example, *teacher education* and *professional learning*. I use the following definitions: *professional learning*, as the general phenomena of teachers' initial and continuing professional development, including both informal, on-the-job aspects as well as more formal programmes of course-based education and training. *Teacher education*, I use for more formal aspects of in-service and pre-service education and training. While in research literature, the terms *professional learning* and *teacher education* are often used interchangeably.

Organisation of this thesis

In this thesis, I begin by introducing the *Bowland Professional Development* materials, in **Chapter 2**. This begins with an overview and description of the PD materials and is followed by a review of research into professional development effectiveness. From this, I develop an analytic framework for assessing the professional development materials. I conclude the chapter with an analysis of the professional learning theory used in the professional development materials.

Chapter 3 develops this further by looking at professional learning theory. I consider theory in relation to mathematics teachers' professional development. From this I introduce *social learning theory* and consider it from the context of this research. I conclude this chapter with the research questions:

1. How do teachers use the professional development materials: what do they attend to and why?
2. How do teachers' self-efficacy beliefs and practices evolve?
3. Which practices do teachers find easiest or most difficult to adopt?

In **Chapter 4**, I describe the research design and the selection of cases. The research used a *mixed-methods multiple case study design* and involved six interconnected studies:

Study 1 Contextual factors (Research question 1).

Study 2 How mathematics departments implemented the professional development materials (Research question 1).

Study 3 Teachers' observations in professional development sessions (Research question 1).

Study 4 How teachers implemented the ideas in the professional development in lessons (Research question 1 & 3).

Study 5 Quantitative analysis of changes in teachers' self-efficacy beliefs and self-reported practices (Research question 1).

Study 6 Qualitative analysis of changes in teachers' self-efficacy beliefs and self-reported practices (Research question 2 & 3).

In **Chapter 5**, I present the results of study 1 and study 2. I look at how the three mathematics departments implemented the materials and the analysis of each department's context. In **Chapter 6**, I present the results of study 3 and 4. I considered what teachers observed in professional development sessions and how they took the suggested ideas into their classrooms. **Chapter 7** describes the quantitative and qualitative analysis of changes in teachers' self-efficacy and changes in self-reported practices from study 5 and 6. In **Chapter 8**, I discuss the results from the previous chapters and interpret the results using *social learning theory*. **Chapter 9** summarises the main findings and presents the implications of this research.

Chapter 2

The *Bowland Professional Development*

In this chapter, I present an analysis of the *Bowland Professional Development* materials. Here, I look at the design of the PD—how the materials are supposed to 'work' and the implicit and explicit assumptions about professional learning. I consider the following questions in relation to the PD materials: *What were the PD materials for? How were the materials designed to be used? What does previous research tells us about the PD materials' potential to be effective?* and *What professional learning theory is implicit in the design of the PD?*

I begin by considering the first question by describing the background to the materials and their overall structure. I then develop an analytic framework derived from research into professional development effectiveness in order to address the second question: *What does previous research tells us about the PD material's potential to be effective?*. From this, I present an analysis of the materials based on the framework. I conclude this chapter with an analysis of the professional learning theory used in the design of the materials.

2.1 Background

The professional development materials were part of the Bowland Maths initiative funded by the Bowland Charitable Trust with support from the Department for Children, Schools and Families (DCSF). The Bowland Maths initiative was a suite of classroom materials that was intended to give Key Stage 3 students (11–14 year olds) chance to engage in collaborative problem solving and was related to the aims of the 2008 National Curriculum (QCA, 2007) which emphasised problem solving.

A suite of professional development materials was developed, this included seven modules (see Table 2.1). The first five modules were designed and developed by the Shell Centre team working in collaboration with the Association of Teachers of Mathematics (ATM) and the Mathemati-

Table 2.1: The Bowland professional development modules.

	Module description
1	The case studies and mathematics
2	Tackling unstructured problems
3	Fostering and managing collaborative work
4	ICT: Using resources effectively
5	Questioning and reasoning
6	Assessing the key processes
7	Involving pupils in self and peer assessment

cal Association (MA). The two later PD modules, modules 6 and 7, were developed by the Shell Centre team.

The professional development materials were proposed by the Shell Centre. As Swan, who led the design, explained to me, teachers required support in teaching using the approaches suggested in the Bowland materials and in the 2008 National Curriculum, because the approach was different from what teachers generally did.

Furthermore, at the time, national funding for professional development was being reduced; there was no national professional development programme to support the introduction of the National Curriculum, even though it proposed substantial changes to teaching. So, the professional development materials had been designed to be used by groups of teachers without the need for an external professional development leader. Swan described how he imagined that teachers in mathematics departments could work together. Thus, the PD materials were a complete set of professional development materials which included handouts, videos of lessons and detailed guidance for the person leading the session.

Each module is structured in the following way:

1. **Introductory session**: teachers are guided through a sequence of activities related to the particular theme of the module, they watch videos of other teachers working on a chosen problem together and in the classroom. Teachers are then encouraged to plan a lesson based on the ideas in the session.

2. **Into-the-classroom**: teachers try out the lesson planned in the *introductory session*.

3. **Follow-up session**: teachers reflect together on their teaching. They look at ways of developing and embedding the approach in the future teaching.

In the next two sections I present an analysis of the PD materials.

2.2 Characteristics of effective PD

Having looked at the purpose and intended applications of the PD materials, in this and the next section I address the question: *what does previous research tells us about the PD material's potential to be effective?*. The aim of this is to develop an analytic framework for the PD materials but also contribute to the development of a conceptual framework for this research.

In this section, I look at prior research into the characteristics of effective PD. I used three studies: the *Researching Effective CPD in Mathematics Education* (RECME) study (Back, Hirst, De Geest, Joubert, and Sutherland, 2009); the *Schools and Continuing Professional Development (CPD) in England – State of the Nation Research Project* (Pedder, Storey, and Opfer, 2008) and the impact research carried out by Desimone, Porter, Garet, Yoon, and Birman (2002). I used the findings from each of these studies to develop a framework of characteristics of PD effectiveness.

The limitation, common to all three, was that the principle sources of data were survey and interviews. No recent study has attempted to connect PD to teacher behaviours and actions through observational studies. I believe the characteristics of effective PD identified in the above studies reflect a consensus in the field of mathematics teachers' professional development research, but with some support from teachers' self-reports about their teaching. Therefore, the overriding feature of the characteristics that I identify here is that they represent a scholarly consensus and as such their status as knowledge must take that into account. Having said this, I accepted them in this research as the best available knowledge.

Reflecting further on this criticism, and as a result of the experience of undertaking this research, I acknowledge the potential difficulties, both methodologically and practically, in designing and implementing research that attempts to identify the factors that make PD effective and identify the causal links with changes in practice. We are dealing with complex and context-specific social systems. My strategy, with the available resources—in this analysis and in the main part of the study—was to take an *analytic* approach.

There are two strategies for generalising results (beyond the acceptance of consensus), the first would be statistical generalisation of the type characterized by field-based experimental analyses, using a representative sample to identify characteristics of effective PD and correlate them with classroom practices. The PD would need to be randomly assigned to determine causality. This study would be a considerable undertaking. The alternative strategy (and a guiding principle for this research as a whole) is *analytic generalisation* (Yin, 2009).

This strategy involves generalising to theory. Findings from individual cases are used to develop and build on broader theory. Theory that can be used to make comparisons between cases where there is a "logical rather than statistical connection between the case and the wider theory" (Cohen, Manion, and Morrison, 2011, p. 294). I discuss this further in Chapter 4,

when I discuss the methodology, but here I introduce this since I use the consensus-based characteristics of effective PD in this chapter.

Looking then at the characteristics of effective PD. The first study, the RECME project (Back et al., 2009), was the most relevant research in relation to the Bowland PD because it focused on mathematics teachers' professional development in England. It involved 30 PD initiatives, overall, about 250 teachers in pre-primary, primary, secondary, further and adult education settings were involved in these initiatives. Two teachers from each initiative were interviewed and observed in their classrooms. The observations were to support the analysis of interviews rather than to identify direct effects of PD on practice. Although, the teacher sample was quite high, the actual number of initiatives was relatively low at 30, with 14 initiatives related specifically to secondary mathematics teachers.

The RECME study identified the following factors that contributed to effective PD:

- The PD is practical and related to classroom practice;
- The leadership of the PD;
- It is stimulating and challenging—it supports the implementation and embedding of change by encouraging teachers to try out new ideas in a supported way;
- Sufficiency of time for professional development (Back et al., 2009, p. 3).

The *Schools and continuing Professional Development (CPD) in England – State of the Nation Research Project* (Pedder et al., 2008) commissioned by the Training and Development Agency for Schools (TDA) offered an alternative perspective, since its aims were to find out the state of CPD in schools: the kinds of professional development that were available in schools, the extent to which teachers participated in different kinds of CPD and the issues that made professional development more or less effective. It was a large-scale mixed-methods project involving a survey of teachers from a representative sample of primary and secondary school teachers in England. There were 1126 responses from teachers and 251 responses from school leaders. In addition, case studies were carried out in three secondary schools, this involved interviews and focus groups to explore the survey results in more depth. Like RECME, it explored what teachers considered to be effective professional development, but also extended to headteachers and school leaders. It was therefore useful to compare the RECME findings with the State of the Nation Study findings.

Teachers identified professional development that involved experimenting with teaching and practice as the most effective (Pedder et al., 2008, p. 34). This was similar to the finding in the RECME study, that effective CPD involved practical activities and was related to classroom practice. It

also considered school leadership perspectives on PD and found the PD was rarely evaluated by schools. This suggested that there was an issue in the way PD was integrated into wider school aims and strategy. This related to the issue of *coherence* identified in the final study which I consider next. I inferred from this, and in the light of my own experience, that PD was often seen as an add-on rather than something that was integrated into the school development plan and the school's operations.

The final study was a three-year longitudinal study involving a purposefully selected sample of 207 teachers in 30 schools from 10 districts across five states in the US (Desimone et al., 2002, p. 81). It focussed on the effects of reform and the extent to which teachers' practices changed. *Reform* represents efforts to change teaching from traditional teacher-centred practices to approaches that foster student understanding and develop problem solving skills.

Although there were potential limitations in using research from the US—there are cultural and systemic differences in the education system, for example—it was useful to consider the findings of this study and make comparisons with both the RECME and the State of the Nation studies.

Desimone et al. (2002) built on the results of their own national cross-sectional sample (Garet, Porter, Desimone, Birman, and Yoon, 2001) which involved a national probability sample of 1027 teachers across 93% of all districts in the US. They hypothesized six key features that would make professional development effective. Three of these they described as "structural":

- "whether the activity is organized as a **reform type**, such as a study group, teacher network, mentoring relationship, committee or task force, internship, individual research project, or teacher research center, in contrast to a traditional workshop, course, or conference" (Desimone et al., 2002, p. 83);
- "the **duration** of the activity, including the total number of contact hours that participants spend in the activity, as well as the span of time over which the activity takes place" (p. 83);
- "... the degree to which the activity emphasizes the **collective participation** of groups of teachers from the same school, department, or grade level, as opposed to the participation of individual teachers from many schools" (p. 83).

A further three factors they described as relating to the "substance of the activity" (p. 83):

- "the extent to which the activity offers opportunities for **active learning**—that is, opportunities for teachers to become actively engaged in the meaningful analysis of teaching and learning, for example, by reviewing student work or obtaining feedback on their teaching" (p. 83);

- "the degree to which the activity promotes **coherence** in teachers' professional development, by incorporating experiences that are consistent with teachers' goals, aligned with state standards and assessments, and encourage continuing professional communication among teachers" (p. 83);
- "the degree to which the activity has a **content focus**—that is, the degree to which the activity is focused on improving and deepening teachers content knowledge in mathematics and science" (p. 83).

Desimone et al. (2002) used these factors in their longitudinal study and analysed the data using structural equation modelling. They found that teachers' participation in professional development that focussed on a particular aspect of teaching was related to an increased use of that practice in their classroom, but in particular conditions. They found the effects varied considerably depending on the aims of the professional development. For example, when the focus was on developing the use of technology, collective participation was a significant factor. When the focus was on the introduction of instructional practices for higher order thinking the significant factor was that it was a reform-type programme i.e. it was a study group, teacher network, mentoring relationship or teacher research rather than traditional course.

Overall Desimone et al. (2002) claimed that "...in our longitudinal study, we found that professional development focused on specific teaching practices increased teachers use of those practices in the classroom" (p. 102). This does not fully characterize the complexity and variation in their results. They also go on to make claims about other factors:

> Our longitudinal data indicate that professional development is more effective in changing teachers classroom practice when it has collective participation of teachers from the same school, department, or grade; and active learning opportunities, such as reviewing student work or obtaining feedback on teaching; and coherence, for example, linking to other activities or building on teachers previous knowledge (Desimone et al., 2002, p. 102).

The statistical evidence was weak, they substantiate their claim by drawing on the results of their cross-sectional study and prior research. There are also some surprising anomalies, they found that the duration of the professional development was not statistically significant in professional development effectiveness.

I integrated the characteristics of effective PD from each study. In particular, I collected the effectiveness characteristics of *practical and related to classroom practice*; *stimulating and engaging* (Back et al., 2009) with *experimenting with classroom practice* (Pedder et al., 2008) and *content focus*; *reform type* and *active learning* (Desimone et al., 2002). I created an overarching characteristic concerned with ***engagement*** which reflected

these overlapping and related characteristics. I summarise the synthesised analytic framework in Figure 2.1. The contributing factors are shown from each study on the left, my derived analytic framework is shown in the final column in bold.

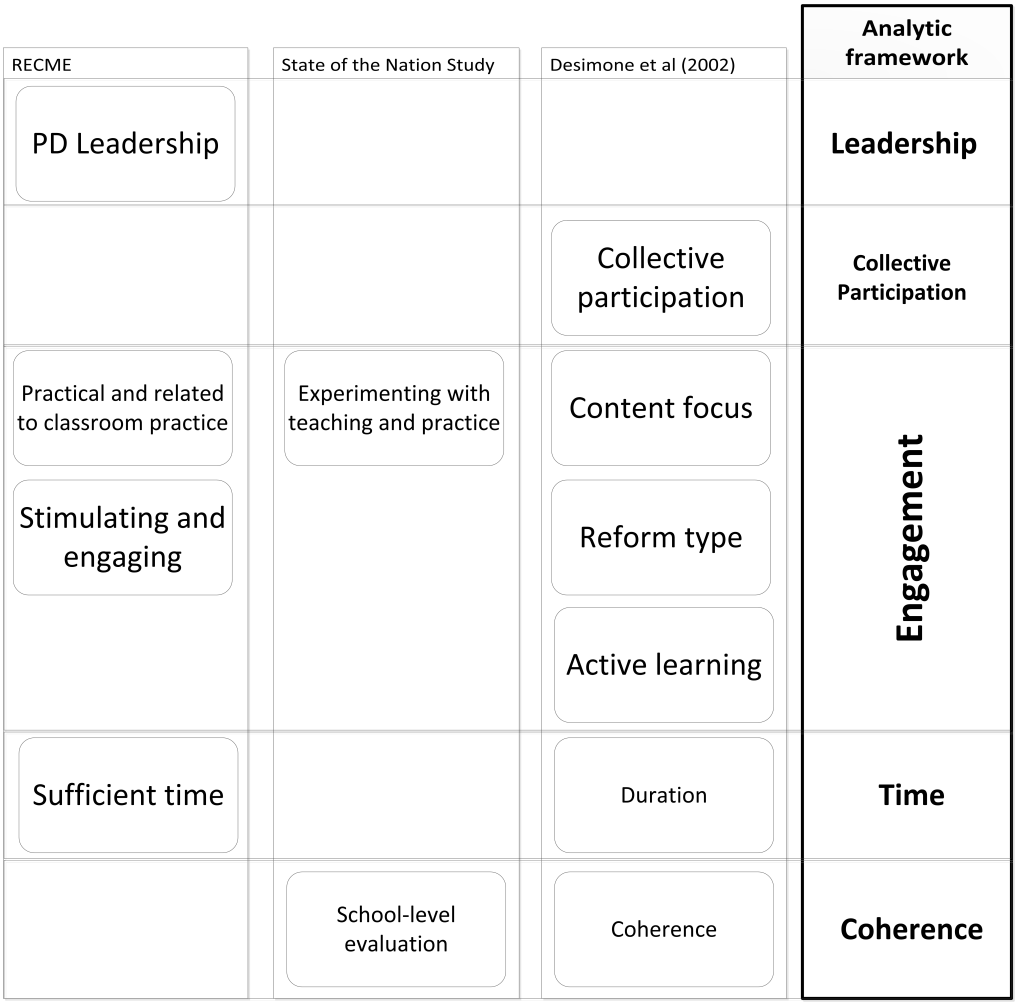


Figure 2.1: Integrated model of PD effectiveness

I summarise the five characteristics of effective PD: ***leadership***; ***collective participation***; ***engagement***; ***time*** and ***coherence*** as follows:

- **Leadership of the professional development** RECME (Back et al., 2009) – This concerned the individual leading the professional development sessions and programme and their leadership style. This was a characteristic that was considered when I looked at the PD in action, since the materials themselves do not reveal anything about the impact of leadership. Save to say that the materials were designed to be used by groups of 'self-led' teachers. I considered this from a *social learning theory* perspective and describe this in the next chapter.

- **Collective participation** (Desimone et al., 2002) – Again, this was something that was explored when the PD was in use in mathematics departments. The assumption was that the more collectively departments participated in the PD the more effective the PD was. I also considered this from a *social learning theory* perspective in the next chapter

- **Engagement** (Back et al., 2009; Desimone et al., 2002; Pedder et al., 2008) – This was a broad characteristic which was the result of synthesising a number of issues identified across all three studies. It included the following sub-characteristics:

    1. The extent to which the materials and the enactment of the materials were engaging and stimulating.
    2. The extent to which participants were active and had opportunity to experiment with practice.
    3. The content and the focus of the PD.
    4. The pedagogical approach used in the PD i.e. the learning approach in the PD sessions.

- **Time** (Back et al., 2009; Desimone et al., 2002) – This related to both having opportunity to participate in professional development, which in turn related to the *coherence* characteristic below and to the length of PD sessions as well as the duration of programmes. In this research I addressed the former aspect of 'time', that is, in relation to teachers being given time to participate in professional learning activities, as a *coherence* characteristic as described next. In this research I did not determine the 'dosage' requirement to make professional development effective i.e. the amount of time required to make PD effective.

- **Coherence** (Desimone et al., 2002; Pedder et al., 2008) – This referred to the extent to which the PD *cohered* with classroom practice, department and school-level policy and practice. I assumed the more the PD cohered with systemic characteristics, the more likely it would be implemented and, moreover, the more likely the aims of the PD were sustained once implemented. It was important, therefore, to consider the policy landscape and the school-level strategy, also to consider the extent to which the PD was integrated into school strategy. It was observed by Pedder et al. (2008) that schools rarely evaluated PD initiatives, suggesting that PD is not well integrated in school-level strategy and therefore it is common that PD does not cohere.

2.3 Analysis of the Bowland PD

In this section, I use the characteristics of effective PD and address the question I introduced at the beginning of the chapter: *What does previous research tells us about the PD material's potential to be effective?* In this analysis, I considered the content of one of the PD modules and assessed the extent to which the PD was likely to be engaging and stimulating for teachers. The analysis of the content involved looking at the mechanisms and processes by which teachers are expected to be engaged with the ideas in the PD. I looked at the following aspects in relation to the focus and presentation in the PD materials:

1. The extent to which the materials are engaging and stimulating.
2. The extent to which participants are active and have opportunity to experiment with practice.
3. The content and the focus of the PD.
4. The pedagogical approach used in the PD i.e. the learning approach in the PD sessions.

As I described at the beginning of the chapter, each module is presented as a 'sandwich' structure with an *introductory* session, an *into-the-classroom* phase and a *follow-up* session.

This structure gives teachers the opportunity to be active and experiment with practice, using the ideas presented in the PD. The *introductory* and *follow-up* sessions are each designed to last for around one hour. From the perspective of engagement, I assumed the session lengths were of a reasonable duration. With sufficient time to allow teachers to engage with the ideas in the PD and sufficiently short to allow attention to be sustained. Although, I found it was difficult for departments to find time for the sessions, this is described in Chapter 5.

The structure allows teachers to engage with the ideas suggested in the PD, to try them out in lessons and then to reflect on and discuss them in the *follow-up session*. This is consistent with what Back et al. (2009), Pedder et al. (2008) and Desimone et al. (2002) found to be effective. From the perspective of *active learning*, PD effectiveness is related to "...opportunities for teachers to become actively engaged in the meaningful analysis of teaching and learning, for example, by reviewing student work or obtaining feedback on their teaching ..." (Desimone et al., 2002, p. 83). With the Bowland PD, teachers are encouraged to reflect on and discuss their attempts to teach using the ideas suggested in the PD, this makes the PD materials potentially engaging in the sense of active learning.

In order to analyse the content more closely, I selected one PD module at random, and looked at the *introductory session* materials in depth. All the module materials follow a very similar format and include a similar

presentation of printed and video materials. I decided the *introductory session* revealed more about the way in which teachers could be potentially engaged with the ideas in the PD, in comparison with the *follow-up* session, which has greater focus on reflection.

At the beginning of the chapter, I explained the purpose and application of the materials. A feature of this was that the materials were designed to be used by a group of teachers with any one of them potentially taking the lead. The material content reflects this in the extensive guidance that is offered to the lead. This includes session plans; handouts (module 3 handouts are included on pages 20 to 23), video material (screenshots from the module 3, *Introductory* session videos are shown on page 19) and a presentation interface referred to as the Bowland player (the main screen for the *introductory* session is shown in Figure 2.2).

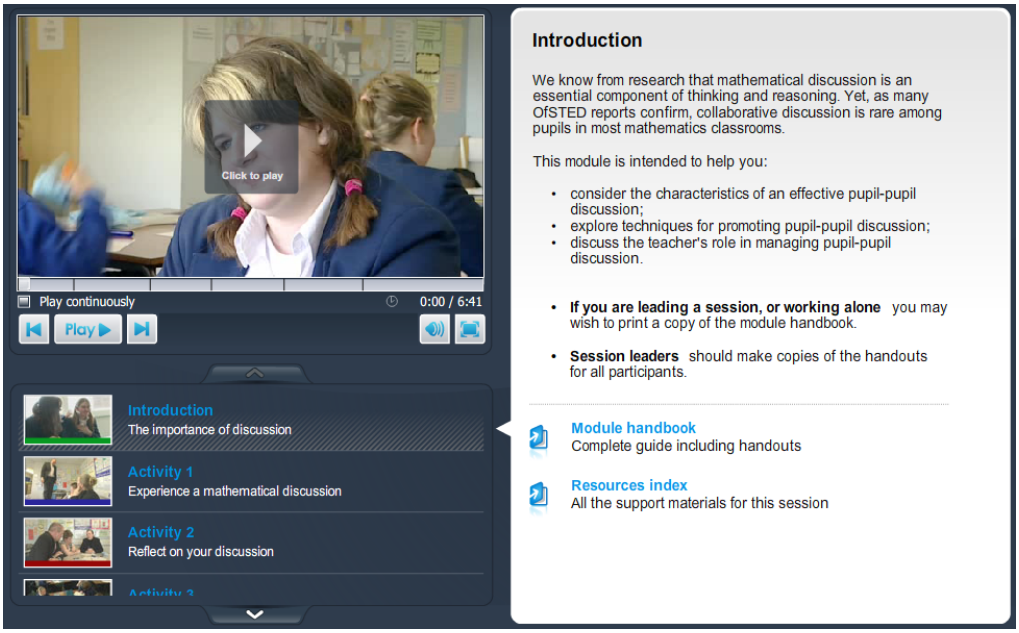


Figure 2.2: Bowland Player screenshot, *Fostering and managing collaborative work* module, introductory session.

Whoever leads the PD can 'deliver' the materials passively; they can use the video to introduce activities and tasks: to explain the ideas and to illustrate the teaching approach. Alternatively, the PD leader can take a more active rôle in the PD and do more of the presentation of the material themselves. In the first case the PD leader is a facilitator, subsuming to the ideas in the materials. In the latter the PD leader takes a leadership rôle, there is a risk, in this case, that the leader may reinterpret the ideas in the PD. It is interesting to note what RECME revealed about PD leadership:

> Some teachers participating in CPD courses suggested that their CPD was effective because of the course leaders (the teacher educators). They suggested it was important that the leader

> had wide knowledge of the field of mathematics education as well as current experience of classroom practice. Other teachers reported that their CPD was effective because, for example, it had a 'good' or 'brilliant' leader, and others pointed out the importance of a leader (Back et al., 2009, p. 75).

The question from this then is, what is the impact of a more passive leadership in PD, one in which the leader is facilitatory rather than authoritative? While I did not look into this in any particular depth, since my focus was on understanding professional learning processes, the effect of leadership has important implications for the implementation of the PD. If, for instance, well-designed PD materials were distributed to schools for mathematics departments to 'implement' it could have the potential to transform teaching. I suspect that in many cases the materials are not enough, change requires local visionary and authoritative leadership as well. I suggest that—and as was found by RECME (Back et al., 2009)—the effectiveness of the PD is dependent on a more dynamic lead: one whose aims are integral to, related with or aligned to those of the materials.

Taking a closer look at PD materials, I selected *module 3*, *Fostering and Managing Collaborative Work*, *Introductory* session for this analysis. Like all the PD sessions, each session is organised into 10- to 20-minute *activities*. I considered these activities in relation to how stimulating and engaging (Back et al., 2009) the materials are. I did not carry out an in-depth analysis but made some simple assessments and judgements about the aspects of the PD materials that appeared engaging and stimulating. This, is in the main, is to articulate the characteristics and nature of the PD materials. How engaging and how stimulating the materials are, is very much dependent on a number of factors: how they are used and how they relate to the perspectives and aims of schools and departments and, of course, how sessions are led.

Each activity has a particular focus and allows time for teachers to give the issue some thought and have some discussion. I consider each activity in turn.

The introduction screen for *Fostering and Managing Collaborative Work*, *Introductory session* (see Figure 2.2) presents the module aims:

- consider the characteristics of an effective pupil-pupil discussion;
- explore techniques for promoting pupil-pupil discussion;
- discuss the teacher's role in managing pupil-pupil discussion.

This reveals the content and focus of this PD module. The focus is pupil discussion in the context of problem solving. Each module has a distinct focus within an overarching theme of teaching to support the development of problem solving skills. I characterized this as a two-level approach:

a pedagogic level, focusing on student collaboration and a content level, focussing on the teaching of problem solving. Each of the seven PD modules has a similar two-level approach. For example, *module 4* involves ICT and problem solving, *module 5* involves teacher questioning and the teaching of problem solving.

There is a possibility that teachers could become more interested in the pedagogic level and not the teaching of problem solving. For instance, it is probably easier to implement the pedagogic features e.g. group-work rather than the substantive aim of teaching problem solving. This chimes with observations made by Cohen (1990) and Cuban (2009), where teachers adopted surface features of reform-oriented PD e.g. changes in room organisation but teaching remained predominantly traditional and teacher-centred. It is what Cuban referred to as *teacher-centred progressivism*. But I elaborate on this further in the next chapter.

After a short introduction, there are five 'activities'. These have the following content:

- **Activity 1: *Experience a mathematical discussion*** This is a 10-minute activity in which teachers have the chance to experience a mathematical discussion. The suggested problem to discuss is 'How many people can stand comfortably on a football pitch?' Alternative problems are also available on handout 1 (see Figure 2.4, p. 20). Participating teachers are encouraged to think about the characteristics of 'helpful' and 'unhelpful' talk. There is also a short video clip of teachers discussing the football pitch problem (see Figure 2.3b, p. 19). This is potentially stimulating and engaging since it gives teachers chance to work on a problem and discuss their approach. In terms of the study by Desimone et al. (2002) it provides opportunity for active learning.

- **Activity 2: *Reflect on your discussion*** This is a further 10-minute activity in which teachers reflect on their discussion. Handout 2 (see Figure 2.4, p. 20) introduces some theoretical perspectives on *discussion*, and raises questions like, is the discussion collective, reciprocal, cumulative, supportive or purposeful? Teachers are also asked to think about what they have learnt mathematically from their discussion. There is supporting video material of teachers reflecting on their discussions (see Figure 2.3c, p. 19). Again this represents opportunity for teacher activity; they are potentially engaged and involved rather than being passive participants.

- **Activity 3: *Observe a discussion lesson*** In this 20-minute activity teachers are expected to look at video of an example of a discussion lesson. There is a brief video clip of a lesson (Figure 2.3d, p. 19), there are also longer video clips of three teachers, Eve, Angela and Marc (see Figure 2.3e, 2.3f and 2.3g, p. 19), each using one of the tasks from handout 1 (Figure 2.4, p. 20) in a discussion lesson.

This activity relates to experimenting with practice. Here the lesson video provides a model which teachers can vary, adapt and implement. Importantly it provides a resource with which teachers can experiment.

- **Activity 4: *Discuss implications for teaching*** In this 10-minute activity, teachers are asked to consider how they might get students to discuss in helpful ways. Handout 3 (Figure 2.5, p. 21) provides 'Ten ground rules' for pupil-pupil discussion. Teachers are asked to think about the way they might encourage students to follow the rules or if they would get classes to draw up their own set of rules. The accompanying video shows Eve introducing a class to the ground rules (Figure 2.3h, p. 19). This is a further 'active' component in which teachers have the chance to consider the ideas.

- **Activity 5: *Plan a lesson using one of the problems*** In the final 10-minute activity teachers are asked to plan a lesson based on one of the problems (handout 1, Figure 2.4, p. 20). The video provides an overview of the activity and includes clips of lessons based on the problems (Figure 2.3i, p. 19). Handout 4 provides some help in planning for pupil-pupil discussion (Figure 2.5, p. 21) and handout 6 provides some notes on the problems (Figure 2.6, p. 22). The last part of the session involves preparation for experimentation; again it is active and includes stimulation in the form of video and printed material.

In sum, the materials themselves involve a wide range of stimuli, including video and printed material and are organised in to a series of 'active' episodes or 'activities'. Taken at face value the materials have many of the features that make them engaging as derived in the model for engagement:

1. The materials have content and activities that appear engaging and stimulating.

2. Participants are potentially active and have opportunity to experiment with practice.

3. The content and the focus of the PD feature a two-level conception: *pedagogy* e.g. student collaboration and a *core focus* of teaching for problem solving. It also provides models and lesson plans for these approaches (see Figure 2.8, p. 30).

4. The pedagogical approach and underlying theoretical approach to professional learning is considered in the final part of the chapter.

(a) **Introduction** *The importance of discussion*, 48′′: video clip describing general issues and their importance in problem-solving.

(b) **Activity 1** *Experience a mathematical discussion*, 1′6′′: clip plus an extra video (3′42′′) showing teachers' discussion.

(c) **Activity 2** *Reflect on your discussion*, 53′′: showing teachers discussing—characterizes 'helpful' and 'unhelpful' talk.

(d) **Activity 3** *Observe a discussion lesson*, 1′2′′: introduction to activity 3, showing Eve's lesson.

(e) **Activity 3** *Observe a discussion lesson*, 11′8′′: of Eve's lesson, 'How many teachers in the UK?'

(f) **Activity 3** *Observe a discussion lesson*, 9′32′′: of Angela's lesson, 'Sharing office space'.

(g) **Activity 3** *Observe a discussion lesson*, 1′12′′: of Marc's lesson 'Treasure hunt'.

(h) **Activity 4** *Discuss implications for teaching*, 1′8′′: introducing activity, showing Eve introducing class to the 'Ten ground rules'.

(i) **Activity 5** *Plan a lesson using one of the problems*, 1′53′′: clip including video of the problems in the session.

Figure 2.3: Screenshots from the video materials for use in the *Fostering and Managing Collaborative Work:* Introductory session.

1 Problems for discussion

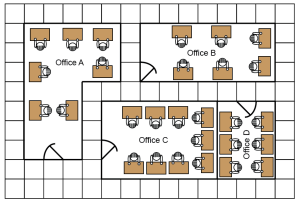
Estimating and interpreting: Schoolteachers and dentists

There are about 60 million people in the UK.

- About how many school teachers are there?
- About how many dentists are there?

Estimate some other facts and check them out!

Modelling and explaining: Sharing office space

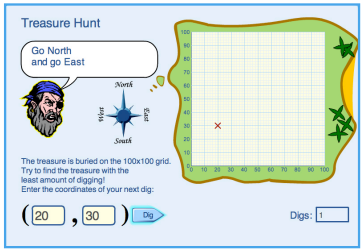


This drawing shows four offices in a factory. The workers complain that some offices are more crowded than others. How could the workers be rearranged with the minimum of fuss, so that the offices are equally crowded?

Solving logic puzzles: Treasure hunt

Type coordinates into the yellow spaces to find the treasure, using the clues given by the pirate.

What advice would you give someone to help them find the treasure with the least amount of digging?



2 Recognising helpful and unhelpful talk

What types of talk engages pupils, develops understanding and promotes deeper thinking? Robin Alexander (2006)[1] identified the following five principles of helpful classroom talk - which he terms *dialogic*.

Dialogic talk is:

- ***Collective***: teachers and children address learning tasks together, as a group or as a class, rather than in isolation
- ***Reciprocal***: teachers and children listen to each other, share ideas and consider alternative viewpoints
- ***Cumulative***: teachers and children build on their own and each others' ideas and chain them into coherent lines of thinking and enquiry
- ***Supportive***: children articulate their ideas freely, without fear of embarrassment over 'wrong' answers and they help each other to reach common understandings
- ***Purposeful***: teachers plan and facilitate dialogic teaching with particular educational goals in view

Neil Mercer (1995, 2000)[2] identifies the following three types of pupil-pupil talk. It is the third type, exploratory talk, that is most helpful fo learning:

Cumulative talk	Speakers build positively, but uncritically on what each other has said. This is typically characterised by repetitions, confirmations and elaborations.
Disputational talk	This consists of disagreement and individualised decision making. It is characterised by short exchanges consisting of assertions and counter-assertions.
Exploratory talk	Speakers work on and elaborate each other's reasoning in a collaborative, rather than competitive atmosphere. Exploratory talk enables reasoning to become audible and knowledge becomes publicly accountable. It is characterised by critical and constructive exchanges. Challenges are justified and alternative ideas are offered.

[1] Alexander, R. (2006). Towards Dialogic Teaching: Rethinking Classroom Talk (3 ed.). Thirsk: Dialogos.

[2] Mercer, N. (1995). The guided construction of knowledge. Clevedon, Philadelphia, Adelaide. Mercer, N. (2000). Words and Minds. London: Routledge.

Figure 2.4: *Fostering and managing collaborative work:* handouts 1 and 2.

3 Ten ground rules for pupil-pupil discussion

Here are some suggested 'ground rules' for **pupils** to use as they work in groups.
These could be displayed and reinforced over time.
Maybe you could involve you class in drawing up a similar list.

1. Give everyone in your group a chance to speak	"Lets take it in turns to say what we think". "Claire, you haven't said anything yet."
2. Listen to what people say	"Don't interrupt - let Sam finish". "I think Sam means that ...."
3. Check that everyone else listens	"What did Sue just say?." "I just made a deliberate mistake - did you spot it?
4. Try to understand what is said	"I don't understand. Can you repeat that?" "Can you *show* me what you mean?"
5. Build on what others have said	"I agree with that because ..." "Yes and I also think that ...."
6. Demand good explanations	"Why do you say that?" "Go on ... convinced me."
7. Challenge what is said	"That cannot be right, because..." "This explanation isn't good enough yet."
8. Treat opinions with respect	"That is an interesting point." "We all make mistakes!"
9. Share responsibility	"Let's make sure that we are all able to report this back to the whole class."
10. Reach agreement	"We've got the general idea, but we need to agree on how we will present it."

4 Planning for pupil-pupil discussion

Plan to offer the task in a form that will encourage collaboration	Prepare shared tasks in a *form* that will encourage discussion. For example: • Provide resources *to share* (e.g. one copy between three) and ask for outputs that are jointly produced. • Provide *big* resources so that reasoning may be visible and shared, such as large sheets of paper, felt-tipped pens or 'mini-whiteboards'. • Require *joint outcomes*: e.g. a poster or a report. Make pupils share responsibility for this.
Plan how you will arrange the room	Arrange tables and chairs so that pupils are facing each other while working together. When computers are used, then pair two pupils to a computer and give them space and resources to record their joint thinking (e.g. using mini-whiteboards). Encourage turn taking when using the computer.
Plan how you will group pupils	Most pupils are more able to discuss in smaller groups than larger ones: pairs or threes is often most effective. Some teachers find a *snowball* approach helpful: • Pupils first tackle the task individually. They have time to think before they are asked to discuss. • Pairs are then formed and pupils are asked to try and reach agreement. • Pairs then join together so that a broader consensus might be reached. • Groups of four then report back to the whole class in a plenary discussion.
Plan how you will introduce the purpose of discussing	Plan your introduction to pre-empt the questions: • "Why do you want us to discuss?" • "What do you want us to discuss?" For example: *This lesson is not about 'me showing you a method and then you using it'. No, I want to see if you can find your own methods. There is more than one way of doing this! I want you to discuss your own ideas for starting on this problem.*
Plan how you will establish ground rules	Introduce ground rules for pupils such as those outlined on Handout 3. Such behaviours are not established overnight, but over a long time through consistent reinforcement.
Plan how you will end the discussion	Most teachers ask pupils to report back on their discussion in some way. All pupils should be encouraged to prepare for this. Try not to pass judgments on their responses while they do this or this may influence subsequent contributions. (See Handout 5)

Figure 2.5: *Fostering and managing collaborative work:* handouts 3 and 4.

5 What is the teacher's role during discussion?

Make the purpose of the task clear	Explain what the task is and how they should work on it. Also, explain why they should work in this way. 'Don't rush, take your time. The answers are not the focus here. It's the *reasons* for those answers that are important. You don't have to finish, but you do have to be able to explain something to the rest of the class.'
Keep reinforcing the 'ground rules'	Try to ensure that pupils remember the ground rules that were discussed at the beginning. Encourage pupils to develop a responsibility for each other's understanding. 'I will pick one of you to explain this to the whole class later – so make sure all of you understand it'.
Listen before intervening	When approaching a group, stand back and listen to the discussion before intervening. It is all too easy to interrupt a group with a predetermined agenda, diverting their attention from the ideas they are discussing. This is not only annoying and disruptive (for the group), it also prevents pupils from concentrating.
Join in, don't judge	Try to join in as an equal member of the group rather than as an authority figure. When teachers adopt judgmental roles, pupils tend to try to 'guess what's in the teacher's head' rather than try to think for themselves: 'Do you want us to say what we think, or what we think you want us to say?'
Ask pupils to describe, explain and interpret	The purpose of an intervention is to increase the depth of reflective thought. Challenge pupils to describe what they are doing (quite easy), to interpret something ('Can you say what that means?') or to explain something ('Can you show us why you say that?).
Do not do the thinking for pupils.	Many pupils are experts at making their teachers do the work! They know that if they 'play dumb' long enough, then the teacher will eventually take over. Try not to fall for this. If a pupil says that he or she cannot explain something, ask another pupil in the group to explain, or ask the pupil to choose some part of the problem that she can explain. Don't let them off the hook! When a pupil asks the teacher a question, don't answer it (at least straight away). Ask someone else in the group to do so.
Don't be afraid of leaving discussions unresolved.	Some teachers like to resolve discussions before they leave the group. When the teacher leads the group to the answer, then leaves, the discussion has ended. Pupils are left with nothing to think about, or they go on to a different problem. It is often better to reawaken interest with a further interesting question that builds on the discussion and then leave the group to discuss it alone. Return some minutes later to find out what has been decided

6 Notes on the problems

Estimating and interpreting: Schoolteachers and dentists

Links to Case Studies

This task offers an unstructured estimation problem. Such problems are intended to create confidence in pupils' own ability to use knowledge that they already have.
This problem is similar to other problems within the Case Studies, most notably those that are contained within the Case Study "**You reckon?"**

Sample solutions

How many schoolteachers are there in the UK?

The solution will be dependent on the assumptions made and the line of reasoning taken. The solutions below illustrate just one approach.

We can make the following assumptions:

- About one fifth of the total population is at school. (If life span is approx 75 years and 14 of these are at school).
- Assume an average of 25 children per class.
- Assume all teachers are working full-time

Then there will be about $\frac{60{,}000{,}000}{5 \times 25} = 480{,}000$ teachers.

Answer: about half a million teachers are required. In fact there are about 441,000 full time teachers in mainstream education (Source: www.statistics.gov.uk)

How many dentists are there in the UK?

We can make the following assumptions:

- Each member of population sees dentist on average twice per year.
- Each consultation lasts about 20 minutes
- Dentist sees patients for about 6 hours per day
- Dentist works for 45 weeks per year.

Then, dentist can have 45 x 5 x 6 x 3 = 4,050 consultations per year.
Number of consultations required = 120 million per year
120 million / 4,050 = 30 thousand dentists

Answer: about 30 thousand dentists are required. In fact there are about 31,000 registered dentists in the UK (Source BBC.co.uk)

Figure 2.6: *Fostering and managing collaborative work:* handouts 5 and 6.

7 Further activities to promote speaking and listening

The following activities are designed for pupils who find it difficult to take it in turns to speak and listen. They do not generate mathematical discussions as such but rather offer a structured format in which pupils can speak for extended periods without interruption.

Back-to-back describing and making.

Ask pupils to sit in pairs, back to back. Give one pupil a picture or a physical object. The pupil then carefully describes the picture or object so that his or her partner can recreate it, without looking. For example:

- One pupil describes a picture (for example, a geometrical design such as the one shown here), the other tries to draw it.
- One pupil describes a 3D construction made from "Lego" or multilink cubes. The other tries to make the same construction using an identical set of material.
- One pupil gives directions to a place, the other draws the route on a map.

After each activity ask pairs to compare their product with the original. What was good about the 'describers' instructions? How might they have been changed to create a more accurate reproduction?

Defining words

Arrange pupils into pairs. Give one pupil in each pair a set of ten mathematical words. (e.g. quadrilateral, parallel, obtuse).
This pupil must try to communicate these words so that their partner can write them down, without using the words themselves, without drawing and without gesticulating in any way. They can only do this by explaining what the word means.

One variation of this game involves banning certain words from being used in the explanation. For example, the pupil may try to communicate the word 'square' without using the words 'four', 'straight sides' and so on.

Sets of cards with suitable mathematical terms (and banned words) are sold under the title "Fourbidden". These may be obtained from the Association of Teachers of Mathematics at http://www.atm.org.uk/buyonline/products/act013.html

8 Suggested further reading:

How can we be sure that the classroom encourages talk for learning? Here is what research shows.
Alexander R (2008) *Towards Dialogic Teaching: rethinking classroom talk* (Dialogos Cambridge
http://www.robinalexander.org.uk/docs/TDTform.pdf

What are the characteristics of talk for learning?
Mercer, N. (2000). *Words and Minds*. London: Routledge.

Improving learning in mathematics – through collaboration
Swan, M. *Improving Learning in Mathematics*, The Standards Unit.
http://www.ncetm.org.uk/files/224/improving_learning_in_mathematicsi.pdf

A research study into the design of collaborative classroom activities
Swan, M. (2006). *Collaborative Learning in Mathematics: A Challenge to our Beliefs and Practices*. London: National Institute for Advanced and Continuing Education (NIACE); National Research and Development Centre for Adult Literacy and Numeracy (NRDC).

Making your interactive whiteboard really interactive.
Tanner H & Jones S (2007) How interactive is your whiteboard?, *Mathematics Teaching #200*, ATM, Derby
http://www.atm.org.uk/mt/archive/mt200files/ATM-MT200-37-41-mo.pdf

This article is about practice in a primary school but has a lot to say to secondary school teachers.
Williamson V (2007) Group and individual work, *Mathematics Teaching #195*, ATM, Derby
http://www.atm.org.uk/mt/archive/mt195files/ATM-MT195-42-45-mo.pdf

Figure 2.7: *Fostering and managing collaborative work:* handouts 7 and 8.

Since the *follow-up* session materials and the other module materials use a similar template and structure, an inspection of the materials indicated that the engagement characteristics are consistent across all the materials. However, as I have explained, this is simply a *face* analysis in order to get a sense of the PD characteristics. In the next chapter, I develop a conceptual framework for identifying underlying processes in terms of how teachers use the materials and how they engage with the materials. For this I used *social learning theory* and observational learning processes which are a component of *social learning theory*.

To conclude this chapter I consider the theory used to conceptualise professional learning in the PD.

2.4 Theoretical basis for the PD design

In this section, I present an analysis of the professional learning theory which underpins the Bowland PD materials. Within the materials there is no explicit account of the underlying theory. During the four years I worked with the Shell Centre the theoretical approach was explained to me by Malcolm Swan. I was also able to analyse research by Swan (e.g. Swan, 2006a,b; Swan, Pead, Doorman, and Mooldijk, 2013) to identify the thinking underpinning the design. Drawing on this evidence, I present the following critique of the theoretical approach.

In brief, the theory underpinning the PD materials is based on the relationship between teachers' beliefs and the way they teach. This follows Swan's previous research and design work in professional development.

A likely origin of this theoretical perspective is a philosophical article by Fenstermacher (1978). He argued against a prevalence of research into teaching effectiveness which was based on a *process-product* approach which he characterized as follows:

> Students in several classrooms are tested before and after instruction. Teachers are observed and their behavior is recorded during the interval between tests. Data from tests are then analyzed in relation the descriptions of teacher performance during the interval, as the researcher attempts to account for varying degrees of student gain from pretest to posttest by identifying relations between student gain (product) and teacher performance (process) (Fenstermacher, 1978, p. 160).

Fenstermacher (1978) criticised the process-product approach because of the difficulty of causality. He argued that teachers' beliefs mediate between process and product and, moreover, for a change in teaching it is necessary to consider and change teachers' beliefs.

Thompson (1984) explored this empirically and sought to identify the nature of the relationship between teachers' beliefs and their teaching. She built on Fenstermacher's (1978) ideas and hypothesised a relationship

between "... teachers' conceptions (their beliefs, views, and preferences) about subject matter and its teaching ..." (p. 105) and the "instructional practices characteristic of their teaching" (p. 105).

Her research was based in the US, she used a case study method with three junior high school teachers. Data collection involved two weeks of observation, followed by a further two weeks of observation *with* post-lesson interviews. Teachers were also given tasks to elicit views about various aspects of mathematics teaching. The analysis was ongoing through the data collection: "As each case study proceeded, the analysis of the accumulated observational and theoretical notes provided new foci for subsequent observation and interviews" (Thompson, 1984, p. 108).

Thompson found two of her case studies, Jeanne and Lynn, viewed mathematics as a "static body of knowledge" (p. 119). Jeanne's teaching focussed on developing conceptual understanding with an appreciation of mathematics "as a set of integrated and interrelated topics" (p. 119). Lynn focussed on the teaching of rules and procedures. The third case study, Kay, held a "dynamic view of mathematics" (p. 109), and "referred to the heuristic processes of mathematics, discussing them independently of the content being studied" (p. 109). Although Thompson acknowledged that the relationship between teachers' beliefs and what they do in the classroom was highly complex, she contended that beliefs "play a significant, albeit subtle role in shaping teachers' characteristic patterns of instructional behavior" (p. 125).

The research was intended to test the hypothesis that teachers' beliefs were related to the way in which teachers behave in the classroom. This is a plausible proposition. What weakens this claim is that there was no attempt to check for rival explanations or rival theory. The study, in itself, would perhaps be reasonable were it not for the fact that this empirical work has been used as the foundation of a subsequent theoretical project which features little further empirical investigation of the relationship between teachers' beliefs and practices.

For example, Ernest (1989) proposed further elaboration to the theory. He suggested:

> ... the practice of teaching mathematics depends on [...] the teacher's mental contents or schemes, particularly the system of beliefs concerning mathematics and its teaching of mathematics and its teaching and learning (Ernest, 1989, p. 249).

Thus, according to Ernest, the way mathematics is taught is dependent on teachers' beliefs about mathematics and mathematics teaching and learning. For example, a teacher who teaches in a traditional way is likely to hold beliefs about mathematics as a static body of knowledge and that learning involves skill mastery. On the other hand, a teacher who adopts a problem-solving orientation sees their role more as a facilitator and that mathematics is a dynamic field of human creation (Ernest, 1989).

Importantly, Ernest recognised that teaching also depends on the "social context of the teaching situation" and the "constraints and the opportunities it provides" (p. 249). However, he focused on the relationship between beliefs and practices in the development of his theory

Swan used beliefs theory as the basis for the design of professional development. He suggested that since much mathematics teaching is traditional and teacher-centred (Swan, 2006a, pp. 44-45), professional development should present a challenge to existing beliefs and allow teachers to develop beliefs that are more consistent with student-centred approaches (p. 173). He illustrated these principles in the context of a professional development programme for mathematics teachers in further education:

> In this project I asked teachers to suspend their current stated beliefs and to act as if they believed differently. I gave teachers 'official' permission to change and provided a culture in which they could do so. An 'official' sanction for the course was given by LSDA [Learning and Skills Development Agency] and an Ofsted inspector. They could always blame us if things went wrong. I attempted to reduce the perceived negative constraints by providing teaching materials consistent with developing theory. Through the use of video, I provided stimuli and I hoped would provoke new anticipations. The teachers used these to help them enact these new approaches. I also encouraged teachers to share their interpretations of what happened. This may have helped teachers to modify their interpretive filters (Swan, 2006a, p. 177).

Swan (2006a) explained that beliefs do not change as a result of recommendation or persuasion but through an experience in which they have opportunity to behave in a way that is consistent with a different set of beliefs. He drew on Guskey's (2002) view of change in this respect.

Swan (2006a) developed a set of principles; these have been used to guide the design of other professional development including the Bowland PD materials:

1. Establish an informal candid culture in which existing beliefs are recognised, made explicit and are worked on in a reflective non-judgemental atmosphere.
2. Illustrate vivid, contrasting practices and discuss the beliefs that underpin these. These may provide 'challenge' or 'conflict'.
3. Ask teachers to 'suspend' disbelief and act in new ways 'as if they believed differently'. Offering mentoring and a network of support as they do this.
4. Encourage teachers to meet together and reflect on their new experiences and the implication that these offer.

5. Ask teachers to reflect on and recognise the growth of new beliefs (Swan, 2006a, p. 178).

In my analysis of the PD materials it can be seen how these are operationalized in the Bowland PD. The introductory session gives teachers chance to reflect on their own perspective. Activity 1 and 2, in the *Fostering and Managing Collaborative Work* module provide space for reflection as new ideas and approaches are introduced. "... vivid, contrasting practices" are illustrated through the use of video. Teachers are then encouraged to "suspend disbelief" and try out the approach in the *into-the-classroom* phase of the PD. Finally, teachers are asked to meet up and reflect on their own experiences in the module *follow-up* session.

The difficulty with the *Bowland Professional Development* materials is that they are not intended to be led or supported by an 'external' expert. A professional development leader who comes from outside the school or department may be in a position to discuss participating teachers' beliefs, while a colleague or head of department may find this more difficult.

There were criticisms of the theoretical relationship between beliefs and practices. There are problems defining beliefs (Goldin, Rösken, and Törner, 2009; Pajares, 1992) and challenges to the validity of the construct, as Mason (2003) argues "[it] is not clear to me that beliefs exist, or that people actually even hold 'beliefs' " (Mason, 2003, p. 288). Social context has an impact on how beliefs become enacted (Ernest, 1989; Gates, 2006; Lerman, 2002; Llinares and Krainer, 2006) and this presents challenges in relating beliefs and practices and this is not taken into account adequately (Gates, 2006; Lerman, 2002). A recent review of beliefs literature concluded that "... beliefs about the teaching and learning of mathematics of teachers at all levels are affected by a range of factors and can be context and student dependant" (Forgasz and Leder, 2008, p. 187). It has been observed that there is often a difference between teachers' behaviours and the beliefs they claim to hold—the difference between enacted and espoused beliefs (Ernest, 1989; Fang, 1996; Skott, 2009).

In spite of the problematic nature of theorizing PD in terms of beliefs, I take a position in this research that reflects the views of Wilson and Cooney (2002):

> [T]here does not appear to a consensus about what constitutes beliefs or whether they include or simply reflect behaviour. Generally speaking neither does there seem to be agreement about the notions of teachers' conceptions or teachers' cognitions. However, regardless of whether one calls teacher thinking beliefs, knowledge, conceptions, cognitions, views, or orientations with all the subtlety these terms imply or how they are assessed [...] the evidence is clear that teacher thinking influences what happens in classroom, what teachers communicate to students, and what students learn (Wilson and Cooney, 2002, p. 144).

It is my view—and based on the evidence in the discussion presented in this section—that there a fundamental problems in relating teacher beliefs with teaching practice. Teacher cognition and thought processes are important. A similar position is taken by Schoenfeld (2010), that the basis for much of our behaviour is underpinned by our intentions and our thinking.

> [W]hat people do is a function of their resources (their knowledge, in the context of available materials and other resources, goals (the conscious and unconscious aims they are trying to achieve), and orientations (their beliefs, values, biases, dispositions etc.) (Schoenfeld, 2010, p. xiv).

However, of importance is the social context (as was identified by, for example, Ernest (1989) and Swan (2006a) and based on my own experience as teacher and head of department) of teaching and the constraints and limitations this presents. In this research and in the development of theory in relation to professional learning, I believed the social context should be accounted for, this prompted me to use a *social learning theory* approach which I describe in the next chapter. At the same time I wanted to account for individual cognition. The integration of a sociological and psychological (Miller and Dollard, 1945) output is a unique feature of *social learning theory*.

2.5 Summary and conclusion

In this chapter, I focussed on the PD materials. In order to explore the materials in depth, I developed an analytic framework through synthesising the findings from three studies concerned with the effectiveness of professional development. I identified four characteristics of professional development effectiveness: *PD leadership*; *collective participation*; *engagement* and *coherence*. I used these characteristics as a framework for analysing the PD materials.

In the critical analysis of the PD materials I considered their potential for *engagement*. Further assessment took place, across all the characteristics, in the main part of this research. At this stage, looking at the materials themselves, I concluded that the PD materials have a number of features that make them engaging. The materials feature a range of presentational devices, including video, graphics and text and are attractive and stimulating. They are organised and structured into a series of active learning episodes. They encourage teachers to experiment with their teaching. Overall, from this analysis, the materials appear engaging. I analysed the materials in terms of their *coherence*. They cohere with National Curriculum aims in that the materials promote student engagement and problem solving. The issue of coherence was further analysed when the PD was used.

Finally, in this chapter, I conducted an analysis of the underlying theoretical assumptions in the PD materials. This is based on a theoretical relationship between teachers' beliefs and practices. I conclude that the teacher thinking, beliefs and perspectives are important in shaping practice. However, it is necessary to take account of the social context and the influence this has on teaching. This I consider further in the next chapter.

In the next chapter, I develop a conceptual framework for this research using *social learning theory* and integrate the effectiveness characteristics identified in this chapter.

BOWLAND MATHS
Professional development

Fostering and managing collaborative work

'How can I get pupils to stop talking and start discussing?'

Into the classroom

The following suggestions describe one possible approach to using the problems with pupils. This may take one or two lessons, depending on the class.

Introduce the problem and pupils think on their own — **5 minutes**

Issue each pupil with a copy of just one of the problems. Introduce the problem to the class. In the case of Treasure Hunt, do a few moves with them on the interactive whiteboard so that they understand what to do.

Explain the purpose of the lesson and give pupils two minutes to think about the problem on their own.

> *The aim of today's lesson is to see how well you can work with a partner to solve a problem. But first I want you to spend two minutes reading the problem quietly on your own so that you have time to think about the problem before you start discussing it. Jot down your own ideas on paper.*

Pupils share their ideas in pairs — **10 minutes**

Explain that you now want them to work in pairs, taking it in turns to share their ideas.

> *Now I want you to work in pairs.*
> *Take turns at explaining your ideas for tackling the problem.*
> *Listen carefully to each other. If you don't understand what is said then challenge your partner to explain themselves more clearly.*
> *When you have both explained your ideas, then try to agree on the best approach together.*

Discuss some helpful ways of working — **10 minutes**

Give out copies of Handout 3 and make the point that people don't learn by simply agreeing or disagreeing, but by following these "ground rules". Ask a few pupils to say which ground rule they find most helpful.

Pupils have another go at the problem — **25 minutes**

Ask pupils to discuss the problem again using the ways of talking in the ground rules. As

Try to listen to pupils' discussions before intervening. Then join in the group asking them gently to describe, explain and interpret without judging their responses as 'good or bad'. Above all, do not do the thinking for pupils.

If possible, tape-record one 5 minute episode of a pupil-pupil discussion, for use in the follow-up meeting.

Pupils share solution strategies — **10 minutes**

Conclude the lesson by inviting pupils to share their reasoning with the whole class. Emphasise that you want to hear *reasoning*, not just their answers. As pupils present their ideas, ask other pupils to comment on the advantages and disadvantages of each approach.

Congratulate them on the ground rules they have used and ask them to consider where they still need to improve.

An optional activity: Pupils watch a video of other people working together

In order to help pupils reflect on the ground rules further you may like to ask them to tackle the problem:

> *How many people can comfortably stand on a football pitch?*

Show the video clip of teachers discussing the same problem (in the *Introductory session* for this module on the DVD/website). Stop the video and ask the class to discuss what was good about the discussion they saw and what could be improved. They might like to begin by commenting on the mathematics and then on the way in which the teachers discussed together. Refer again to Handout 3.

Figure 2.8: *Fostering and managing collaborative work* PD module, into the classroom, Suggested lesson plan.

Chapter 3

Social Learning Theory

This chapter builds on the ideas presented in the previous chapter. Here, I consider theory in relation to mathematics teachers' professional development. I draw on previous research as a platform for this and undertake an analysis of existing perspectives in order to derive a theoretical framework for the research.

In the previous chapter, I presented an analysis of the *Bowland PD materials*. I used an analytic framework which I developed from a review of research into what makes professional development effective. A criticism of that research was related to the methodological challenge in determining what makes PD effective. I saw this challenge in terms of relating processes and actions in the PD to what goes on in the classroom.

The research I examined in the previous chapter suggested that professional development is sensitive to context and, importantly, how complex those contexts are. Taking the example of the study undertaken by Desimone et al. (2002), results were influenced by the type of PD and context (with a number of complex variables representing *context*). PD research is implicitly difficult to generalise. If a statistical approach to generalisation were adopted, there would be difficulties in controlling variables and establishing causality through the random assignment of the PD.

In this chapter, I attempt to address this issue and introduce theory that has the potential to be overarching in respect to reform-oriented professional development for mathematics teachers. That is, where the aims of the PD are intended to support mathematics teachers in moving away from or supplementing prevalent teacher-centred practices. Although, I believe the theory I present here, has much wider potential application in teachers' professional development.

In the first part of the chapter I review research to illustrate the lack of overarching theory and that PD research does not have a strong theoretical base.

In the second part of the chapter, I introduce *social learning theory* as a potential overarching theory; I present a critical analysis of *social learning theory* and consider mathematics teachers' professional development from this perspective. Finally, I integrate the analytic framework

developed in the previous chapter—the PD effectiveness characteristics of *leadership*; *collective participation*; *engagement*; *time* and *coherence*—with *social learning theory*.

I begin with an analysis of research into mathematics teachers' professional development to demonstrate the lack of overarching theory; from this I justify the choice of *social learning theory* as a guiding theory in this research.

3.1 Research into mathematics teachers' professional development

In this section, I present an analysis of the characteristics of research into mathematics teachers' professional development. For this purpose, I drew on an extensive review of research conducted by Adler, Ball, Krainer, Lin, and Novotna (2005). I selected this review since it was the most comprehensive review, carried out in recent years of research in this area: it was unique in its scale and scope. However, I do not rely solely on one review—in spite of its comprehensiveness—I compare the claims arising from this review with other research and positions espoused by prominent researchers.

Adler et al. (2005) reviewed research into both initial teacher education as well as the professional development of practising mathematics teachers; the findings of this review provided a valuable basis for understanding the field of research into mathematics teachers' professional learning. They analysed a range of research published internationally over a period of four years between 1999 and 2003. They considered 300 papers relating to teacher education, further elaborated through a focussed study of 160 papers. The main finding was that the majority of papers related to small-scale, qualitative studies:

> ... there are 98 (out of 160, more than 60%) papers where there were fewer than 20 teachers in the study. Taking out those 15 papers that don't include empirical data or don't claim to be empirical, the percentage is even near 70% (98 out of 145). Hence, we observed that a significant percentage of papers are small case studies (Adler et al., 2005, p. 369).

They inferred from this, that because teacher education research is an emerging field, it was likely that the character of the research was exploratory and not concerned with developing knowledge and theory, "... it is a natural state that particularization comes before generalization for an emerging field" (p. 370). However, the authors also pointed out the drawbacks in this, in terms of developing understanding of professional learning in a more general sense. They pointed out the absence of particular types of studies, such as, large-scale studies, cross-case analyses and longitudinal studies.

My assumption based on this, and consistent with Adler et al. (2005), was that professional development research lacks a general theory in relation to teachers' professional learning. This was supported by further observations they made that the majority of studies into teacher education were carried out by teacher educators studying the teachers they were working with. This has the potential for biased results and one way of limiting bias is to have an overarching theory.

Of the articles they reviewed in the *Journal for Research in Mathematics Teacher Education* (JMTE), 90% were of this type. In the *Proceedings of Psychology of Mathematics Education Conferences* (PME), 82% of the papers reviewed were teacher educator research into teachers they were working with. This, the authors argued, is reasonable since teacher educators are, as part of their work, interested in evaluating their programmes and approaches. However, the authors pointed out the risk that this proximity may have in leading to biased results: there is a danger that teacher educators may over-claim the effectiveness or impact of programmes or methods. One of the authors (Adler) was critical of the fact that the motives underpinning much teacher education research are actually counterproductive in the development of an overarching project or the development of professional learning theory.

> When you have an investment in which you are teaching, it can be difficult to take a skeptical stance towards that work. Important questions that need to be asked might be missed. So, one critical question is what we need to do to help ourselves take such a skeptical stance towards that work. One way is to invite "external eyes" to gaze in with us on what we are doing is to develop strong and effective theoretical languages that enable us to create a distance between us and what we are looking at. We need to do more to develop strong language(s) of description for researching mathematics teacher education (commentary by Adler from, Adler et al., 2005, p. 372).

What this research described, and was consistent of my own investigation of the field, is that there is lack of "strong and effective theoretical language" not only, as Adler et al. (2005) suggested, in order to create distance between the teacher educator as researcher and the object of the research, but also in order to make comparisons and synthesise the findings of the small-scale qualitative studies that are prevalent in the field.

What I concluded from the review carried out by Adler et al. (2005) is that there has been limited development of a coherent project across studies. Professional development research is characterized by localised, individual efforts driven, in the majority of cases, by researchers'/ teacher educators' agendas or particular areas of interest. Indeed, others have drawn similar conclusions about mathematics teachers' professional development research subsequently. Jaworski (2006) considered there to be a lack of 'big' theory. Rösken (2011) pointed to the diversity and near

fragmentation of theory. Consistent with Adler et al.'s review, theory in mathematics teachers' professional development research is underdeveloped (Borko, 2004; Clarke and Hollingsworth, 2002). Similar characterisations have been made about theory in teachers' professional development research more generally (Opfer and Pedder, 2011).

This prompted me to identify theory for this research that might contribute to the field by providing an overarching perspective and theoretical language for making comparisons between studies of professional development. My proposal in this respect is *social learning theory* which I introduce in the next section. Before coming to this I want offer a further point of reference in my discussion of the field of mathematics teachers' professional development. To do this I draw on the review by Joubert and Sutherland (2008).

The literature review, as part of the *Researching Effective CPD in Mathematics Education* project (RECME) (Joubert and Sutherland, 2008), attempted to theorize mathematics teachers' professional learning as part of the process of identifying features of effective CPD from previous research. The range of research included professional development for teachers in pre-university phases of compulsory and non-compulsory education in England. The review methodology does not endeavour to be systematic unlike the review undertaken by Adler et al. (2005). However, the attempt to theorize professional learning is important. Since, and as was pointed out by Adler et al. (2005), there is a need to develop a theoretical language to synthesise the findings of what are often small-scale teacher-educator lead studies. Joubert and Sutherland (2008) drew on theory developed by Eraut (1994).

What is particularly important in Eraut's (1994) work is the consideration of informal learning—tacit knowledge that is communicated in complex ways from experienced practitioners to novices—as well as more formal learning, such as, participation in courses or programmes. Eraut (1994) recognised the strength of informal learning in comparison to the formal aspects of professional learning. Informal learning has greater influence over professionals' behaviour and practice than formal courses.

> Teachers predominantly learn through practice, developing personal knowledge related to teaching and learning that is mostly tacit, uncodified and difficult to uncover. By contrast cultural knowledge includes the codified knowledge of the academic community and the know-how of the profession. Whereas CPD tends to focus on cultural knowledge, the literature suggests that very little of this is usable as it stands. It has to be transformed into a form that suits the user's practical context and purpose (Joubert and Sutherland, 2008, p. 27).

Eraut's perspective is also consistent with *social learning theory*, as I will discuss in the next section. The drawback with Eraut's theory is that it is based on the study of professional development in other fields.

To summarise this section: I considered a review which characterized professional development research as small-scale, qualitative and lacking the development of overarching theory (Adler et al., 2005). A second review (Joubert and Sutherland, 2008) synthesised existing research and used theory developed by Eraut (1994) to explain professional learning as a complex interplay between informal (tacit on-the-job learning) and formal (PD courses and programmes).

As a consequence, I identified the need for theory in this research that had sufficient scope to explain professional learning and that had the potential to provide an overarching theoretical language. One characteristic identified in this review was that theory (following on from Eraut, 1994) should account for both formal learning and informal tacit learning. This was influential in my selection of *social learning theory*. In the next section I introduce this theory and examine its appropriateness.

3.2 *Social learning theory*

I focus here on *social learning theory* (also referred to as *social cognitive theory*) as developed by the Canadian psychologist Albert Bandura. I selected this theory because it offers a comprehensive theory of learning and behaviour and has the potential to provide a theoretical language for professional development as suggested by Adler et al. (2005). My use of this theory in this research builds on my own previous analysis (Watson, 2013) based on Schoenfeld's framework (2008) for assessing theory.

Social learning theory also reflects the issue I identified in the previous chapter, that is, the importance of individual learning and the effects of the social setting. As Miller and Dollard (1945) pointed out, a *social learning theory* perspective integrates the perspectives of psychologists with those of the sociologists. This has become an emergent but prominent feature of my analysis so far—in professional learning it is important to consider individual learning and cognition and the effects of the social and cultural setting concurrently.

Social learning theory consists of three components: *observational learning*, *reciprocal determinism* and *self-efficacy* (see, Bandura, 1977, 1986, 1997). I will describe and present a critical analysis of each of these in turn and in the context of mathematics teachers' professional development for problem solving.

3.2.1 Observational learning

Central to *social learning theory* is observational learning: that we learn primarily by observing others' behaviour. Building on the work of earlier social learning theorists (in particular, Miller and Dollard, 1945), Bandura conducted a study of how aggressive behaviour might develop in children as a result of observing aggressive and violent behaviour. This research

was, in part, prompted by an interest in the effects of television violence on children. In these observational experiments (Bandura, Ross, and Ross, 1961) tested 36 boys and 36 girls from the Stanford University Nursery School aged between 3 to 6 years old. They observed adults' violent behaviour toward a Bobo doll. They found that the children not only imitated the behaviour of the adults, but also developed novel violent behaviours based on what they had observed, "...subjects learnt to combine fractional responses into relatively complex novel patterns solely by observing the performance of social models" (Bandura et al., 1961, p. 580). The researchers concluded that the children had constructed new patterns of behaviour based on the patterns they had observed.

From this Bandura developed a theory of observational learning in both children and adults. Although he based his theory principally on this kind of experimental research, he also provided justification from general observations that observational learning is a necessity in order that new behaviours can be developed without continual trial and error. This builds on previous work by Miller and Dollard (1945). He proposed that learning takes place through two types of mechanism: *response consequences* or learning through *modelling*, thus, he suggested, "new response patterns can be acquired either by direct experience or by observation" (Bandura, 1977, p. 16). Direct experience or response consequences are a result of the positive and negative effects that our actions produce and the influence that has on our behaviour i.e. trial and error. He summarised his argument for observational learning as follows:

> [F]rom observing others[,] one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action. Because people can learn from examples what to do, at least in an approximate form, before performing any behavior, they are spared needless error (Bandura, 1977, p. 22).

This claim relies heavily on experimental studies involving young children (for example, Bandura and Huston, 1961; Bandura et al., 1961). Although it is reasonable to assume that when adults are required to learn new behaviours, observational learning is an important mechanism. The biggest drawback is that Bandura did not draw on studies of observational learning of adults. Moreover, there are limited empirical studies into observational learning in teacher education or indeed education more generally.

Having said this, observational learning has not escaped prominent researchers in education, although not from a *social learning theory* perspective. For example Lortie (2002) described the importance of observational learning in becoming a teacher as an *apprenticeship of observation*.

> Those who teach have normally had sixteen continuous years of contact with teachers and professors. American young people, in fact, see teachers at work much more than they see any other

> occupational group; we can estimate that the average student has spent 13,000 hours in direct contact with classroom teachers by the time he graduates from high school (Lortie, 2002, p. 61).

Lortie's idea of an *apprenticeship of observation* is based on a synthesis of his and others' research but is not directly substantiated through empirical study. Stigler and Hiebert (1999) made similar claims, as part of the TIMSS video study: through the observation of teaching, as a student and as a student teacher, a teacher constructs a mental model of teaching.

Stigler and Hiebert's (1999) influential work, *The Teaching Gap*, used video-recordings of an international sample of eighth-grade mathematics teachers. Lesson videos were coded and from the analysis Stigler and Hiebert were able to build up a description of teaching in each country. From this they claimed the existence of similar patterns of practice in each of the three countries, USA, Germany and Japan. Their explanation of why teachers, within a culture, followed similar patterns within lessons was based on observational learning. They introduced the idea of a "cultural script" which is "...generalized knowledge about an event that resides in the heads of participants" (loc. 1098). They elaborate further:

> These scripts guide behavior and also tell participants what to expect. Within a culture, these scripts are widely shared, and therefore hard to see (Stigler and Hiebert, 1999, kindle edition location (loc.) 1098).

This is consistent with a *social learning theory* perspective on observational learning. "Cultural scripts are learnt implicitly, through observation and participation, and not by deliberate study" (Stigler and Hiebert, 1999, loc. 1102). They proposed that professional learning takes place and practices sustained through observational learning.

> Teaching, like other cultural activities, is learned through informal participation over long periods of time. It is something one learns to do more by growing up in a culture than by studying it formally.
>
> Although most people have not studied to be teachers, most people have been students. People within a culture share a mental picture of what teaching is like. We call this mental picture a *script*. The script is, in fact, a mental version of the teaching patterns we have observed [in the research]. (Stigler and Hiebert, 1999, loc. 1112-1116).

Observational learning represents a plausible explanation for learnt behaviour. However, in the context of teaching, it has not been explored directly in research—there is an absence of empirical study. Yet here, I hypothesized that observational learning plays an important part in the way traditional teacher-centred practices are learnt and sustained. I also

suggest that observational learning can be used to explain how teachers might learn new approaches and patterns. I therefore used observational learning—within the wider framework of *social learning theory*—as a basis for theorizing professional learning.

Observational learning sub-processes

I also wanted to go deeper into this and have a framework from which I could analyse teachers' observational learning in the context of the PD. This was prompted by my interest in understanding what it was teachers noticed and attended to in the PD sessions and in regard to the PD materials as a whole. This also related to my discussion of *engagement* presented in the previous chapter. Using a theoretical framework provided the basis for understanding the processes of professional learning in closer detail—the '*how?*' and '*why?*' of transferring ideas in the PD into the minds of the teachers and on to the classroom.

For this I used Bandura's observational learning sub-processes (1977) (summarised in Figure 3.1). These are *attention*, *retention*, *production* and *motivation*.

Attentional processes control how individuals explore and perceive observed behaviours. *Retentional processes* involve the transfer of the observed behaviour into "symbolic conceptions" (Bandura, 1986, p. 51) which provide, "internal models for response production" (p. 51). *Production processes* involve the conversion of the symbolic codification of observed behaviours into action and finally the *motivation processes* address how, out of the numerous behaviours observed and symbolically retained, certain behaviours are constructed and enacted (1986, p. 51).

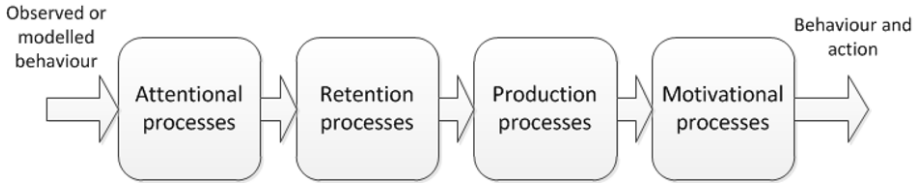


Figure 3.1: Observational learning sub-processes (Bandura, 1986, p. 52).

I considered the *attentional processes* in investigating what it was that teachers attended to and noticed in using the PD . These determine what is selectively observed and, according to Bandura (1986, pp. 51-52), are dependent on the model (the observed behaviour) and on the observer.

The characteristics of the modelled events (the behaviour that is being observed) that Bandura (1986) identified were: *salience*, *affective valency*, *complexity*, *prevalence*, *accessibility* and *functional value*. These characteristics suggest that observed behaviour has certain noticeable aspects that must stand out or have some form of emotional significance. Observed behaviours must also have the appropriate degree of complexity—complex

enough to be interesting and have value, but not too complex as to be inaccessible. The idea of *prevalence* suggests that that observed behaviour has some degree of authority. Finally, the observed behaviour must appear to have use: it must have *functional value*.

In terms of observer attributes, Bandura (1986) suggested the following attentional sub-processes of observational learning as: *perceptual capabilities*, *perceptual set*, *cognitive capabilities*, *arousal level* and *acquired preferences*. The observer, in order to observe behaviours, must therefore have the appropriate cognitive and sensory powers in order to observe behaviours (perceptual capabilities) at the same time predispositions must not place the observed behaviour outside of sensory perception (perceptual set). At a cognitive level, the observer must have the appropriate capabilities and at an affective level, they must have appropriate levels of arousal.

I further investigated how teachers implemented the ideas presented in the PD. For this I used the *production* and *motivational processes* as frameworks. *Production processes* are the mechanisms by which teachers convert symbolic conceptions into action. According to Bandura (1986) action is a consequence of, "...organizing responses spatially and temporally in accordance with the conception of the activity" (p. 63).

Conception-matching processes take place as part of *production processes*. This involves cognitions of response patterns, initiation of response and matching action to conception through making adjustments to behaviour. Actions are based on combining components into new patterns which may be a complex and multi-faceted skill.

Motivational processes reflect the distinction made in social learning theory between, "acquisition and performance" (Bandura, 1986, p. 68). In other words, a person can acquire the knowledge of how to do something but may never use it. There are three sources of motivation to implement observed behaviours: "direct, vicarious, and self-produced" (1986, p. 68).

Direct sources of motivation are where external incentives reward certain observed behaviours (see, Bandura and Barab, 1971, cited in Bandura, 1986, p. 68). Vicarious sources of motivation mean that those observed behaviours that appear to be effective for others are preferred (see, Bandura, 1965b, cited in Bandura, 1986, p. 68). Finally, self-produced sources of motivation are personal preferences and reflect personal values (Hicks, 1971, cited in Bandura, 1986, p. 68).

Retention processes represent the symbolization of observed behaviour. While, Bandura (1986, pp. 56-57) considered there to be two representational systems—imaginal and verbal constructions—I also consider there to be a narrative dimension that is episodic rather than as relatively static images and verbal 'rules'. The episodic nature of memory also carries with it an *affective signature* (Nespor, 1987).

Overall, the decisions people make to take various courses of action and behave in particular ways is dependent on self-efficacy beliefs. People do the things they believe they are more likely to do be successful with. As such it is important to distinguish between having the capacity to make

something happen and the mechanisms by which it take place. "... people try to generate courses of action to suit given purposes..." (Bandura, 1997, p. 3).

While Bandura developed the observational sub-processes theoretically, as has been his style, he drew on evidence from his and others' studies of observational learning (see, for example: Abravenal, Levan-Goldschmidt, and Stevenson, 1976, cited in Bandura, 1986, p. 51). Therefore, I believed it was reasonable to use this as a framework to analyse teachers' observational learning in this research and provide explanation for observational learning in relation to the PD. I explain how I did this in more detail in the next chapter.

In this section I have considered observational learning as a component of *social learning theory*. I now move on to another aspect, that of reciprocal determinism.

3.2.2 Reciprocal determinism

A further important concept in *social learning theory* is that of *reciprocal determinism* which is also referred to as *triadic determinism*. This suggests the reciprocal relationship between environment, the individual and behaviour. Unlike the other components of *social learning theory*, reciprocal determinism provides a higher-level organising principle which links together observational learning and self-efficacy. As such, reciprocal determinism does not lend itself to direct empirical testing but is indirectly supported with evidence from the investigation of observational learning and self-efficacy.

What is important about reciprocal triadic determinism is that it is the conceptual basis, in *social learning theory*, for linking the psychological with the social setting and cultural context. Observational learning has greater emphasis on individual learning and psychological processes, even though there are implicit and necessary social processes. Reciprocal determinism conceptualises the relationship between the cognitive and social and places observational learning within an organising scheme.

The most effective way of explaining reciprocal triadic determinism is through a description of the way it was developed by Bandura (1977). He began with a fundamental symbolic representation of behaviourism, $B = f(E)$. Behaviour, B, is a function of environmental stimuli, E. This is a behaviourist view of the formation of behaviour: our behaviours are a response to external stimuli. From the direct response to stimuli there grew interest in individual thought and cognition in the formation of behaviour. This is later developed to give $B = f(P, E)$. So, behaviour, B, is actually some function of the individual, P, and the environment, E, —the person is not a passive responder to stimuli, the individual contributes to their behaviour with their own ideas and motivations. Bandura then considered there to be reciprocal interaction between the individual, P, and the environment $B = f(P \longleftrightarrow E)$. Now the individual is represented as

having an influence on their environment and *vice versa*. Behaviour is a function of this reciprocal interaction. Bandura's final move was to make this relationship triadic and reciprocal (see Figure 3.2).

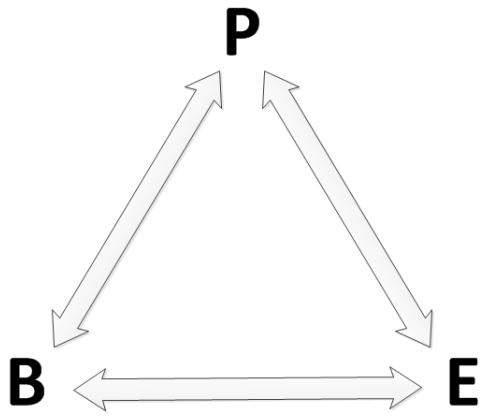


Figure 3.2: Reciprocal determinism (Bandura, 1977, p. 10) B signifies behaviour, P the person and E the environment.

Bandura summarised it thus:

> Personal and environmental factors do not function as independent determinants, rather they determine each other. Nor can 'persons' be considered causes independent of their behavior. It is largely through their actions that people produce the environmental conditions that affect their behavior in a reciprocal fashion. The experiences generated by behavior also partly determine what a person becomes and can do which in turn, affects subsequent behavior (Bandura, 1977, p. 9).

In such a way then, the social context influences the individual's behaviour and thinking. How we think and behave is influenced by the social, environmental and contextual setting and can be seen as the individual responding to prevailing norms and modes of behaviour. At the same time thinking and behaviour influence the social setting and environmental context (and indeed permits us agency). This aspect of *social learning theory* further contributed to my decision to use this theory. As I highlighted earlier, it was important that professional learning theory account for both individual cognition as well as the social effects. Reciprocal determinism provides a theoretical basis for this observation.

Like with observational learning, prominent scholars in professional development research have also proposed that research should consider *individual thinking* as well as the *social influence* on learning, although they made no reference to *social learning theory*. Most notably, Borko (2004), argued for a *situative* perspective in professional development research. This

is how she characterized a *situative* perspectives in relation to classroom research.

> Research in a situative tradition allows for multiple conceptual perspectives and multiple units of analysis. These multiple perspectives provide powerful tools for understanding student learning in classroom settings. Using psychological conceptual frameworks and the individual as the unit of analysis, researchers can study students' activities as individuals and their evolving knowledge and understanding. They can use sociocultural conceptual frameworks and the group as the unit of analysis to examine the social context of the classroom and patterns of participation in learning activities. Both perspectives are essential to understanding how students learn through participation in classroom practices (Borko, 2004, p. 4).

This can be applied to professional learning where we consider teachers as individuals from a psychological perspective and as participants in groups in departments and schools. Within the *situative* perspective, reciprocal or triadic determinism can be seen.

There is further evidence of a reciprocal deterministic perspective abroad in professional development research. Clarke and Hollingsworth (2002) proposed an *Interconnected Model* of PD, which has much in common with the situative approach suggested by Borko (2004). The *Interconnected Model* linked a *personal domain* of knowledge and beliefs with the *external domain* of information and stimuli and the *domain of practice* which is concerned with professional experimentation (Clarke and Hollingsworth, 2002, pp. 950–951).

The literature review conducted as part of the RECME study (Joubert and Sutherland, 2008) also identified the situated nature of professional learning. It drew on broader professional learning literature and points to the complex interplay between *informal* on-the-job learning and *formal* learning as part of a PD programme (Eraut, 1994).

The introduction of reciprocal or triadic determinism is an important move in this research. It marks a significant development in thinking about learning and in particular the professional learning of mathematics teachers. Mathematics education research is influenced by two groups of theory (for an analysis of this, see Lerman, 2002, for example).

The first, *constructivism*, is influenced by the thinking of Vygötsky and Piaget. While there is a great deal of variance in *constructivist* learning theory, similar principles are shared: that thinking and cognition is influenced by the social context, situation or environment and learning processes are principally psychological (Schunk, 2013, p. 232). Cognition then influences behaviour. The influence of the constructivist perspective can be seen in the discussion of teacher beliefs. Teachers construct beliefs about teaching and learning mathematics through contextual experience—to change

beliefs requires a reconstruction through challenging existing beliefs combined with experience. Similar principles underlie professional learning associated with teacher knowledge.

A second theoretical position has been given increasing attention. This gives greater emphasis to the influence of social context on behaviour through participation in discourse communities and through *peripheral participation* (Lave and Wenger, 1991; Wenger, 1998).

Social learning theory, in terms of reciprocal determinism, brings these two strands together. Drawing attention to this and utilising an integrating theory is, I believe, an important part of the contribution of this research.

In sum, reciprocal determinism proposes that individual thinking, behaviour and the social setting are reciprocally related. As such, in this research I consider contexts, social settings, cultural settings and individual experiences within these contexts, as well as individual cognitive processes as teachers learn through observation and in relation to their existing knowledge and perceptions.

In the next section, I consider the final component of *social learning theory*, self-efficacy.

3.2.3 Self-efficacy

The final component of *social learning theory* is self-efficacy, I use the following definition:

> *Perceived self-efficacy refers to beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments* [original emphasis] (Bandura, 1997, p. 3).

According to Bandura, a person who is efficacious in a domain or set of activities is more likely to be successful in those activities. In other words, if you believe you can complete an activity successfully or believe that you will be effective in a particular field, the chances are you will be successful and effective. Of course, there are examples where we might encourage ourselves or talk ourselves in to doing something—effectively making ourselves believe that we will be successful. For example, I might convince myself that I am good at cricket, where in fact my performance in this sport is quite limited. What I would have done in this example has been to enhance the judgement of my own effectiveness. However, this self-concept is decoupled from my actual skill levels. Bandura is careful to distinguish self-efficacy from other concepts of 'self'. A key idea in the concept of self-efficacy is the coupling of self-perception with underlying skill.

It is therefore important to recognise the subtle difference between the concept of self-efficacy and other views of 'self', for example, self-concept or self-esteem. Self-concept is related to self-efficacy but refers to attitudes to one's self or self-images. It does not include the forward-orientation of

self-efficacy or have a strong relationship with action or behaviour. Similarly, self-esteem is concerned with judgements of self-worth, this contrasts with self-efficacy which is concerned with beliefs about capabilities and the potential to achieve certain levels of attainment (Bandura, 1997, pp. 10–11).

As I have carried out this research and also explained its theoretical basis, a frequent question that arose was: *isn't self-efficacy the same as confidence?* Although the concepts of individual confidence and self-efficacy have similarities, there are important differences, as pointed out by Bandura:

> ... the construct of self-efficacy differs from the colloquial term *confidence* [original emphasis]. Confidence is a nondescript term that refers to strength of belief but does not necessarily specify what the certainty is about. I can be supremely confident that I will fail at an endeavor. Perceived self-efficacy refers to belief in one's agentive capabilities, that one can produce given levels of attainment. A self-efficacy assessment, therefore, includes both an affirmation of a capability level and the strength of that belief. Confidence is a catchword rather than a construct embedded in a theoretical system (Bandura, 1997, p. 382).

Thus, self-efficacy reflects an individual's underlying knowledge or skill-level, as well as their capacity to deploy these effectively and strategically to achieve successful outcomes. This explains why people with similar knowledge and skills can perform very differently.

> Efficacy beliefs operate as a key factor in a generative system of human competence. Hence different people with similar skills, or the same person under different circumstances may perform poorly, adequately or extraordinarily depending on fluctuations of personal efficacy (Bandura, 1997, p. 37).

To support his theory, Bandura drew on experimental studies that provided evidence of causation i.e. the causal link between self-efficacy and behaviour. The issue is that self-efficacy is a "postulated cognitive mediator" (Bandura, 1997, p. 54) and is not directly observable. In other words it is a construct that can be measured or assessed directly. To overcome this Bandura proposed an approach based on a "dual causal linkage" (p. 54), where external behavioural influences were observed, the effects on perceived self-efficacy were reported and subsequent behaviour observed. When variation in efficacy beliefs was controlled for and no relation existed between external influence and behaviour then external influence was mediated through efficacy beliefs. Therefore by drawing on his own and others' experimental studies of causality (see, Bandura, 1997, pp. 54–61), he provided supporting evidence for his theory or at least in a Bayesian

sense i.e. there is an increased probability that this theory is the most likely explanation of the causal relationship between phenomena.

While this provides supporting evidence for the mediating rôle of self-efficacy beliefs and for self-efficacy theory more generally, there are challenges in measuring self-efficacy beliefs.

Although self-efficacy cannot be observed directly, self-efficacy scales have been developed by Bandura (1997, 2006). These have been validated by observing performance and comparing achievement with individuals' perceived self-efficacy (Bandura, 1997, pp. 46–47). Bandura claimed that carefully constructed self-efficacy scales can reveal individual perceived self-efficacy in a particular domain (Bandura, 1997, 2006). The strategy for developing self-efficacy scales involves a description of the context e.g. teaching a year ten class mathematics followed by a series of items related to aspects of that activity. These items are worded in the form "how much can you do to get through to the most difficult students?" (Tschannen-Moran and Woolfolk Hoy, 2001). Respondents are asked to rate their success on scales of 1 to 9. I will return to the teacher efficacy scale developed by Tschannen-Moran and Woolfolk Hoy shortly.

I used Bandura's methodology in the design of a teaching problem solving efficacy instrument which I describe in the next chapter.

What is critical in developing efficacy scales is specifying the domain of activity and the components of the overall activity. Bandura explained that self-efficacy is not a general characteristic of the individual but is related to specific areas of activity or domains. This reflects the difference between self-efficacy and other 'self' concepts: the close relationship between self-efficacy and activity. Bandura explained thus:

> Personal efficacy is not a contextless global disposition assayed by an omnibus test. Rather, it is a multifaceted phenomenon. A high sense of efficacy in one domain is not necessarily accompanied by a high self-efficacy in other realms (Bandura, 1997, p. 42).

This can be problematic when it comes to measuring self-efficacy. Bandura found that specifying task and activities that contribute to the domain of interest is the major challenge in quantitative analysis of self-efficacy (Bandura, 2006). This is especially true for teaching which is a multi-faceted, complex activity and set of behaviours with myriad sub-skills. However, Bandura and others (for example Tschannen-Moran and Woolfolk Hoy, 2001; Tschannen-Moran, Woolfolk Hoy, and Hoy, 1998) have proposed that there is a valid concept of teacher self-efficacy, that is it is reasonable to talk of a general concept of teacher self-efficacy.

Considerable work has been done in developing teacher self-efficacy scales by Tschannen-Moran and Woolfolk Hoy (2001) and Tschannen-Moran et al. (1998). They defined a teacher's self-efficacy as:

> ... a judgement of his or her capabilities to bring about desired outcomes of student engagement and learning, even among

> those students who may be difficult or unmotivated (Tschannen-Moran and Woolfolk Hoy, 2001, p. 783).

They developed an instrument which drew on previous instruments and items used in measuring teachers' self-efficacy. Previous teacher self-efficacy instruments revealed sub-dimensions and factors within teaching self-efficacy. I suggest, this reflects the complexity of teaching.

Tschannen-Moran and Woolfolk Hoy (2001) found that these prompted considerable confusion and debate. They acknowledged that there would be factors within a teacher self-efficacy measure and so, as part of the process of their instrument development, they carried out a study involving 217 teachers in Ohio State (although they did not specify whether the teachers were primary or secondary). They then carried out a series of factor analyses and item development until they identified three subscales. These were: *efficacy for student engagement*, *efficacy for instructional strategies*, and *efficacy for classroom management*.

I used this instrument in this study; I explain how self-efficacy relates to PD in the next section and how I used the instrument in the next chapter.

They conducted a final factor analysis with another 410 students. They analysed the construct validity of their final teacher efficacy scale by correlation with factors in previous measures and concluded that the new instrument was a much improved measure of teacher self-efficacy. It has been used widely subsequently. It has been validated across different cultures through analysis of teacher responses across five countries (Klassen, Bong, Usher, Chong, Huan, Wong, and Georgiou, 2009).

Tschannen-Moran and Woolfolk Hoy (2001) concede limitations in their own measure.

> Clearly this new scale needs further testing and validation. Clarification of the meaning of teacher efficacy and the relative weight of teachers' assessments of their skills and liabilities in light of the resources and constraints they face in particular teaching contexts promises to aid both those who would study and those who train teachers (Tschannen-Moran and Woolfolk Hoy, 2001, p. 802).

However, what is important is that the development of this instrument both theoretically and empirically has been more comprehensive and rigorous than other constructs related to teacher characteristics. I refer back to my discussion of teacher beliefs and draw attention to the limited development of that construct in comparison. It is this that drew me first to self-efficacy theory and second to *social learning theory* as a novel theoretical basis for mathematics teachers' professional development: one that has the potential to offer a cross-study theoretical language for teachers' professional learning. It is by no means perfect but the rigour and development is advanced in comparison to alternatives.

The question is, how does self-efficacy relate to mathematics teachers' professional development? A number of studies have offered evidence that the more efficacious a teacher, the more likely they are to innovate and experiment with their teaching (Berman and McLaughlin, 1978; Guskey, 1988; Stein and Wang, 1988).

A large-scale study of educational reforms and innovations; the way they were implemented and the extent to which they were sustained, was carried out by the Rand Corporation in the USA (Berman and McLaughlin, 1978; Berman, McLaughlin, Bass-Golod, Pauly, and Zellman, 1977). This study revealed that the teacher characteristics that influenced the likelihood of change and the continuation of that change were years of teaching and sense of efficacy. Teachers with many years in teaching were less likely to change their practices. While teachers with a strong sense of efficacy were most likely to change and sustain that change (Berman and McLaughlin, 1978, p. vii).

Abrami, Poulsen, and Chambers (2004) applied a related concept, expectancy theory, to a PD context. Expectancy theory has three main components: value, expectancy and cost (Abrami et al., 2004, p. 203). The assumption is that a teacher will implement an innovative approach if, a) they value the approach, b) they believe they will be successful with it (expectancy) and c) if the perceived cost of implementation is reasonable. Abrami et al. (2004) found that *expectancy* was the most important component—how successful teachers believed they would be in implementing the approach.

Therefore, those teachers with high levels of teaching self-efficacy in ideas presented in PD, were more likely to implement the new ideas in their teaching than less self-efficacious teachers. Put another way, the more confident and motivated teachers are, the more likely they are to take and use the new ideas.

It is also important to consider how the PD materials impact on teacher self-efficacy. The PD materials were designed to support changes in teacher beliefs and as a result changes in teachers' practices. It would be reasonable to make a parallel analysis of changes in teachers' self-efficacy beliefs. What would the impact be of the PD programme, based on the materials, on teacher self-efficacy? A small number of studies have used an experimental methodology to assess the effects of professional development on teachers' self-efficacy (see, for example Karimi (Allvar), 2011; Ross and Bruce, 2007). These revealed that professional development can have an effect on teacher self-efficacy. This is a useful since self-efficacy offers a useful teacher characteristic as a dependant variable. In this research self-efficacy was used as a construct to explore the effects of the PD both quantitatively and qualitatively.

Finally, I want to consider the sources of self-efficacy for the purpose of the analysis in this research. Bandura proposed four sources of self-efficacy: *enactive mastery experience*, *vicarious experience*, *verbal persuasion* and *physiological and affective states* (Bandura, 1997, pp. 79–113). *Enactive*

mastery experiences offer the most powerful sources of self-efficacy beliefs. If we are successful in something our efficacy will increase, if we fail it will be undermined. Easy successes prompt an expectation of quick results but can lead to being easily discouraged by failure (Bandura, 1997, p. 80).

Self-efficacy can also be developed through *vicarious experience*, this provides an alternative and complementary source where individuals assess their own abilities and capabilities based on the attainments and successes of others. Bandura illustrates the process:

> More often in everyday life, people compare themselves to a particular associate in similar situations, such as classmates, work associates, competitors, or people in other settings engaged in similar endeavours (Bandura, 1997, p. 87).

Comparing our performances with others leads to increases in self-efficacy; if we believe we can be at least as effective as the person observed.

A further but weaker source of self-efficacy is through *verbal persuasion*. If an individual is persuaded that they have the abilities and capacities to achieve a particular level of success this will have an influence on whether the outcome of their performance is successful. However, if the persuasion is unrealistic then this can undermine the individual performance and also discredit the persuader (Bandura, 1997, p. 101).

Finally *physiological and affective states* have an effect on self-efficacy. If we feel ill or we are in a bad mood this will have an impact in the extent that we believe we will be successful. This according to Bandura, is especially relevant in areas related to "physical accomplishments, health functioning and coping with stressors" (Bandura, 1997, p. 106) and of consequence in teaching where high levels of stress are often experienced. Self-efficacy can be enhanced by improving physical status, reducing levels of stress and correcting misinterpretations of bodily states: effectively improving our physical condition and the way in which stress is dealt with, as well as having an improved understanding of our physical self.

Klassen, Tze, Betts, and Gordon found that "... most researchers uncritically defer to Bandura's hypothesis that there are four sources of self-[efficacy]" (Klassen, Tze, Betts, and Gordon, 2011, p. 39). Tschannen-Moran and McMaster (2009) carried out a quasi-experimental study of elementary teachers in the US participating in four types of PD with the aim of identifying the relative strengths and effects of different sources of self-efficacy. They found that *verbal persuasion* and *vicarious experience* with limited *mastery experience* did not support the introduction of a new teaching approach. They found that an "authentic task-specific mastery experience" and "individualized verbal persuasion" (Tschannen-Moran and McMaster, 2009, p. 242) were important in raising efficacy to support the implementation of a new approach.

This resonates with the aims of the PD materials and the context of this research, where an important aspect of the PD is the *into-the-classroom*

phase where teachers have the opportunity for *authentic task-specific mastery.*

The review carried out by (Klassen et al., 2011) led to a conclusion that teacher efficacy is a valuable teacher characteristic in teacher professional learning research, but they suggested there have been too few qualitative investigations of efficacy, particular aimed at developing an understanding of the sources of self-efficacy beyond Bandura's proposed four sources. I recognised this also and as a consequence, I decided to investigate changes in teacher self-efficacy both quantitatively, using a teaching self-efficacy instrument, and qualitatively, which involved case studies of individual teachers. Although, in this research I accepted Bandura's (1986, 1997) four sources of self-efficacy: *mastery*, *vicarious experience*, *verbal persuasion* and *physiological and affective states.*

To summarise this section, I introduced the final component of *social learning theory*, self-efficacy. I discussed the complexity of specifying what teacher self-efficacy is: on account of the complexity and multiplicity of behaviours and actions in teaching. I then demonstrated how, from the evidence in previous research, efficacious teachers are more likely to implement new approaches to teaching. I also showed how professional development can be considered in terms of changes in teacher self-efficacy. I also demonstrated how teacher self-efficacy can be measured but also the importance of the qualitative analysis of teacher self-efficacy and how self-efficacy might develop through a PD programme.

This concludes the first part of this chapter in which I introduced and discussed *social learning theory* and its three sub-constructs: *observational learning*, *reciprocal determinism* and *self-efficacy.* In the final part of this chapter I bring together these aspects to present a theoretical framework for this PD based on these elements.

3.3 Professional learning from a social learning perspective

In this section, I bring the components of *social learning theory* together to consider mathematics teachers' professional learning in the context of this research. I also integrate the issues identified in the previous chapter on the analysis of the PD materials. I began by examining assumptions presented in Chapter 1, about the prevalence of traditional teacher-centred teaching in secondary mathematics and examine this from a *social learning theory* perspective. Following this I consider professional development from a *social learning theory* perspective.

The ubiquity of teacher-centred teaching

OfSTED characterized traditional teacher-centred teaching approaches as follows: "In the secondary lessons [observed], the most prevalent style was

one where the teacher demonstrated a new mathematical method which pupils then practised" (OfSTED, 2008, p. 16). I use *social learning theory* to explain how this is sustained through observational learning and how self-efficacy explains why such practices are ubiquitous in secondary mathematics classrooms. This leads on to explaining how professional development might lead to change.

In the first part of this chapter, I explained how observational learning is a component of *social learning theory* and tells us that behaviours are learnt through observation. Teachers participate in an *apprenticeship of observation* (Lortie, 2002), as trainee and new-qualified teachers. They adopt "cultural scripts [that] are learned implicitly, through observation and participation" (Stigler and Hiebert, 1999, loc. 1102).

A further proposition from *social learning theory* is that where there is little or no motivation to do otherwise, behaviours becomes automatic or routinized. Much human behaviour once learnt does not require constant redesign—we do not have to rethink everything we do each time we do it. "After people develop adequate ways of managing situations that recur regularly, they act on their perceived efficacy without requiring continuing directive or reflective thought" (Bandura, 1997, p. 34). Once teachers have learnt to teach and have developed practices and approaches that permit them to function in their rôle, they do not have to think about and plan every detail of every lesson and everything they do in each lesson. They have access to a range of behaviours and lesson patterns that simply work. Acting on "perceived efficacy" means that a teacher believes that those actions will be successful. Thus, routines of teacher-centred practice can be implemented reasonably reliably.

Leinhardt (1988) observed a number of lessons over a lengthy research career. She derived a similar theory of practice to that which I developed from *social learning theory*.

> Situated knowledge can be seen as a form of expertise in which declarative knowledge is highly proceduralized and automatic and in which a highly efficient collection of heuristics exist for the solution of specific problems in teaching. This automation or resistance to change on the part of the teacher should not be perceived as a form of stubborn ignorance or authoritarian rigidity but as a response to consistency of the total situation and a desire to continue to employ expert-like solutions (Leinhardt, 1988, p. 146).

This, although not from a *social learning theory* perspective, is consistent with Bandura's proposition of developing behavioural routines that meet the needs and demands of situations that recur regularly. Leinhardt enriches this idea with the introduction of "heuristics". Although teaching behaviours become 'proceduralized' and automated, teachers are not simply automatons; they use patterns of previously used actions and classroom

behaviours to meet the needs of the classroom situation. Lienhardt suggested that by using 'proceduralized' and automatic knowledge, teachers are able to act in sophisticated ways but without having to think about, in detail, every action and response in their teaching.

Leinhardt's heuristics are consistent with *social learning theory*. Bandura (1997) explained how observational learning can be a generative process, where observed behaviour can be used as a guide for action rather than something that it is directly imitated and replicated. Generativity in observational learning is consistent with Leinhardt's notion of heuristics. The difference is that *social learning theory* goes on to attribute the sources of behaviour to observation.

So far I have provided support for the formation of patterns of practice, but why would these tend toward a teacher-centred approach? And, why should these practices be similar within a culture or within a country?

In order to answer these questions, I draw on the historical analysis of classrooms in the US carried out by Cuban (1993). An historical analysis is useful because it provides insight into the development of practice. Cuban explained the formations of particular patterns and approaches through this. For the second question I draw, once again, on the comparative study of practice carried out by Stigler and Hiebert (1999) but consider a retrospective analysis of Stigler and Hiebert's assumption that practice is similar within a culture or jurisdiction by (Givvin, Hiebert, Jacobs, Hollingsworth, and Gallimore, 2005). From this analysis I demonstrate that it is reasonable to assume that traditional teacher-centred practice is a default teaching style: that it is reasonable to assume that there are similarities within a culture and that observational learning offers an explanation why.

Cuban (1993) examined the practices and teaching patterns found in classrooms in the US between 1880 and 1990. His starting point is similar to the observations made by Stigler and Hiebert (1999) that teaching followed similar approaches within a culture and seemed to remain largely unchanged over time.

Cuban's (1993) study was located in the US, across all subject teaching and in both elementary and high school settings. So, how is this useful in the English context? The reason I view Cuban's research as important is that he attempted to explain the similarities that might be observed in teaching within a culture. This explanation can be applied to the English context and be used to account for the similarities that are observed in English secondary mathematics classrooms. Cuban's explanation, as I will justify, is not specific to context.

Cuban drew on a number of sources of evidence in his analysis: photographs of teachers and students in class; textbooks; student recollections; teacher reports on how they taught; reports from journalists, administrators and others who visited classrooms; student writings school newspapers and yearbooks; research studies of teaching practices; and description of classroom architecture, room size, desk design and building size. He acknowledged the historian's dilemma of selectivity of evidence (p. 13) but

"sought multiple and divergent sources representing ... a number of different settings" (p. 13). He gathered descriptions of 1200 classrooms in the period 1890 to 1990; he combined this with his broader data set and so claimed to have an "indirectly" derived picture of teaching practices in 7000 classrooms.

He acknowledged the difficulties in describing practice. "Anyone familiar with a classroom knows the kaleidoscope whirl that it is ... How can I capture only one slice of this whirl after it has disappeared?" (Cuban, 1993, p. 14). Yet this is what he attempted to do, with a range of assembled secondary evidence. In order to facilitate this Cuban adopted a framework for describing teaching using the idea of teacher-centred and student-centred practices. He characterized teacher-centred teaching as follows:

- Teacher talk exceeds student talk during instruction.
- Instruction occurs frequently with the whole class; small-group or individual instruction occurs less often.
- Use of class time is largely determined by the teacher.
- The teachers rely heavily upon the textbook to guide curricular and instructional decision making.
- The classroom furniture is usually arranged into rows of desks or chairs facing a chalkboard with a teacher's desk nearby (Cuban, 1993, pp. 6-7).

Cuban's justification for the prevalence of teacher-centred teaching provides the most convincing argument for the prevalence of teacher-centred approaches to teaching because it is consistent with my own experience of teaching in English secondary schools.

> Within these schools and classroom settings, teachers have learned to ration their time and energy to cope with conflicting and multiple societal and political demands by using certain teaching practices that have proved over time to be simple, resilient, and efficient solutions in dealing with large numbers in a small space for extended periods of time (Cuban, 2009, p. 10-11).

This has the same underlying logic as posited by Leinhardt (1988) and also that which I derived from *social learning theory*. Teachers deploy a range of traditional teacher-centred teaching approaches as a result of the demands of the rôle and as a result of constraints arising from having finite resources in state-funded education. This also contains some implicit reference to what teachers might consider to be effective in teaching mathematics. That is, the lesson runs smoothly and is well-managed. This means then, that the primary goal of teaching is not necessarily optimising learning but effective management of the classroom and behaviour. I am not saying that teachers do not value student learning, but there are often more pressing needs concerned with classroom management.

Cuban's argument is related to Bandura's proposition that "people develop adequate ways of managing situations that recur regularly" and act on their perceived efficacy (Bandura, 1997, p. 34). However, Cuban offered a deeper analysis of adequacy in practice. So taking Bandura' theory and Cuban's historical analysis together: within the demanding rôle of teaching and the resource-constrained school institution, teachers have self-efficacy in traditional teacher-centred approaches and those practices will be effective in managing classrooms and behaviour. They may not offer the optimal learning experience but they do allow lessons to run smoothly.

I think it is important to consider the rôle of the student as a participant in classroom routines. Stigler and Hiebert considered students, as well as teachers, as following a cultural script:

> . . . one of the reasons classrooms run as smoothly as they do is that students and teachers have the same script in their heads: they know what to expect and what rôles to play (Stigler and Hiebert, 1999, loc. 1121).

This reflects the idea of a didactical contract:

> Then a relationship is formed which determines – explicitly to some extent, but mainly implicitly – what each partner, the teacher and the student, will have the responsibility for managing and, in some way or other, be responsible to the other person for. This system of reciprocal obligation resembles a contract. (Brousseau, 2002, p. 31).

Traditional teacher-centred teaching is a feature of an equilibrated system, where patterns of behaviour have been shaped over time and transmitted through observational processes through generations. This is largely a consequence of the constraints and demands of the job of teaching. Where primacy rests in teachers having smooth running classes and classrooms. It also rests on not having to think through every action in a lesson. This, in many ways, contradicts Schoenfeld's (2010) assertion that 'in-the-moment decision-making' is influenced by goal orientation. From a *social learning theory* perspective, teachers' in-the-moment decision making in classrooms is a result of having a range of mentally modelled actions gained through observational means, that have been rehearsed in the course of experience and that are ready to be deployed heuristically.

From my analysis here, *social learning theory* provides the more likely explanation of teachers' actions and behaviours and hence my decision to use it for explaining professional learning in this research, but also as a potential overarching theory for reform-oriented professional development. My next consideration is how teachers might introduce new methods and approaches in a sustainable way.

A summary of the *social learning theory* model of professional development

In this section, I present a summary of the model of professional learning based on *social learning theory* that I used in this research. I begin with the two components of social learning theory that I operationalised: *observational learning* and *teacher self-efficacy*.

Observational learning

In this research, I used *observational learning* as an explanation of how teachers (potentially) learnt new practices. It is important to have some process or mechanism by which new or alternative ideas are potentially implemented. I chose *observational learning* (as a component of social learning theory) as it offers a framework for analysis and explanation as part of a wider theory. It allowed me to focus in on aspects of individual learning. I looked at the observational processes that groups of teachers used in PD sessions and looked at how individual teachers translated these ideas into lessons. I used the observational sub-process of *attention* in order to analyse teacher behaviour in the PD sessions. In case studies of individual teachers, I considered how teachers took ideas presented in various parts of the PD, whether it be video examples of lessons or in printed lesson plans, and adapted them to their own classrooms. I was particularly interested in the *generative* aspect of observational learning and how teachers take and adapt an idea or alternative approach.

Teacher self-efficacy

The implementation of a new approach relies on teachers being efficacious in that approach. In this study I was interested in making assessments about initial levels of efficacy in the teaching of problem solving. I assumed the more willing teachers were to implement the approaches and ideas suggested in the PD, the more efficacious they were. I was also interested in understanding how teaching efficacy might be affected by the PD. I chose to look at this quantitatively using existing teacher efficacy instruments and a problem-solving specific instrument developed for this research. I also decided to look at individual changes by considering case studies of individual teachers. I elaborate on this in the next chapter.

I used the four sources of self-efficacy proposed by Bandura (1997) as analytic framework for the qualitative research, these are: *mastery experience*, *vicarious experience*, *verbal persuasion* and *affective and physiological states*. The most important source of self-efficacy when using the PD materials is through *mastery experience*, the chance to experience success in using the ideas in a lesson. It is likely that the other sources will also play a rôle too. *Vicarious experience* might provide opportunities for developing self-efficacy though watching the video examples or working with colleagues. Teachers, if they identify with another individual, assess their

effectiveness more positively as a result of observing another being successful in implementing the new approach.

Verbal persuasion is a weaker source of self-efficacy, but may encourage teachers to try out ideas in the first instance which then leads to the development of mastery and in consequence self-efficacy in the approach. Finally, *affective and physiological states* can undermine self-efficacy—if stressed or ill, teachers will be less efficacious and this will limit the impact of new ideas. This is important since teaching can be highly stressful and a teacher is frequently faced with multiple and often competing demands on their time and energy. As such a stressful or demanding context is not conducive to reform because teachers tend to feel less confident in implementing new ideas.

Integrating the characteristics of effective PD with *social learning theory*

Having summarised a model of professional learning using *observational learning* and *teacher self-efficacy*, I wanted to integrate the analytic framework I derived from previous research on professional development effectiveness, described in the previous chapter. I could therefore relate the findings of this research with existing research, at least in terms of the consensus of ideas and characteristics. For example, I considered the rôle of PD leadership, collective participation etc. in relation to social learning theory and in terms of the data. In other words, I considered the impact of these characteristics and provided an explanatory analysis using *social learning theory*.

I consider each of the characteristics of effective PD (*leadership*; *collective participation*; *engagement*; *time* and *coherence*) and integrate them with social learning theory.

PD leadership

From a *social learning theory* perspective, leadership contributes in two areas. The first is in relation to observational learning processes. Using Bandura's theory of observational sub-processes (*attentional processes*, *retention processes*, *production processes* and *motivational processes*), I considered *attentional* processes and *motivational processes* as most relevant here. The PD leader has a rôle in making the PD content relevant and salient to individual teachers and in encouraging them to try things out. Therefore, one aspect of PD leadership is in facilitating observational learning.

The second contribution of leadership is in developing teacher self-efficacy. PD leaders can promote self-efficacy through *verbal persuasion*. While it is considered weaker than *mastery experience* or *vicarious experience*, it contributes to teachers' motivation to try the approaches out,

which in turn would lead to the development of self-efficacy through mastery experiences.

Collective participation

Prior research has claimed this to have a positive impact on the effectiveness of professional development (Back et al., 2009; Desimone et al., 2002; Stoll, Bolam, McMahon, Wallace, and Thomas, 2006). From a *social learning theory* perspective, collective participation contributes to teacher self-efficacy in terms of vicarious experience and verbal persuasion. Seeing a colleague try a new approach out in their classroom and being successful can be a source of self-efficacy. Although, if relationships were not strong in the mathematics department, this might have the opposite effect.

Bandura (1997) put vicarious experience in terms of "referential comparisons" (p. 87), in other words, comparing your own performance with others or as "attribute similarity" (p. 98). In the latter a teacher would be looking to identify with a similar teacher as a model and a vicarious measure of the level of success.

Another source of self-efficacy in collective participation is through verbal persuasion i.e. supporting and encouraging each other. In a highly individual and competitive department self-efficacy could be undermined or if indeed relationships were poor and there was limited trust: there would be no recognition of similar attributes.

Collective participation, from a *social learning theory* perspective, is therefore a necessary but not sufficient condition for PD effectiveness. It is possible that collectivity could undermine effectiveness under certain conditions, like for instance if there were a lack of trust or if there were no existing collaborative culture.

I considered the effects of collective participation from the perspective of two efficacy sources: vicarious experience and verbal persuasion. I did not go into this in any great depth as I was particularly interested in observational learning and teacher self-efficacy. I made assessments of how effectively departments collaborated and the culture of those departments as part the analysis of *coherence* characteristics (see below).

Engagement

In the previous chapter I used this term as a catch-all for a range of related factors which had been derived from prior research. These included:

- The PD was practical and related to classroom practice;
- It involved experimenting with teaching and practice;
- It involved active learning;
- It focussed on mathematics content and pedagogy;

- It was of a 'reform-type' i.e. it did not involve teachers participating in a lecture-style programme.

From the viewpoint of *social learning theory*, the underlying connecting theme is that the PD offers opportunity to try things out, rehearse ideas and experiment. This is related to the strongest source of self-efficacy that of *mastery experience*. It also implies having models and ideas that can be adapted and experimented with, this is a feature of *observational learning*. In the previous chapter, in relation to this idea, I looked at how stimulating and engaging the materials were. In the empirical part of the research I was concerned with how the materials were used and the way in which mastery experiences happened and also observational learning processes.

Time

This factor is concerned with the impact of the duration of PD sessions, modules and the programme as a whole. I considered this by looking at how departments used the PD materials.

Coherence

In the previous chapter, I identified a characteristic of effective PD for which I used an umbrella term of 'coherence'. This I took from the research conducted by Desimone et al. (2002). Their conception of this was:

> ... the degree to which the activity promotes *coherence* in teachers' professional development, by incorporating experiences that are consistent with teachers' goals, aligned with state standards and assessments, and encourage continuing professional communication among teachers (Desimone et al., 2002, p. 83).

This is a broad issue relating to a range of contextual factors. Another way of looking at this is from what Cooney and Krainer (1996) considered the *macro* and *micro* issues of PD. They saw the *macro* issues as coming from society: economics, politics, culture and language, for example. The *micro* issues include things like curriculum, assessment and existing practices. Similarly, Llinares and Krainer (2006) considered professional learning as not just involving the individual, but as located in a social and organizational context. In fact PD is located within a national education system, a society and culture.

Krainer (2006) developed this further and proposed a framework of *content*, *communities* and *context*. *Content* refers to the PD, its aims and how it will be carried out. *Communities* refer to those doing the PD and the *context* refers to determinants and influencing factors at school, district and national level. I consider, therefore, building on the conceptualisation of Krainer (2006) and the idea of *coherence* (Desimone et al., 2002), that policy, practices and culture in schools and the education system are important in determining how the PD is implemented. These are large issues

existing in a complex multilevel system, so what aspects are important to consider?

I considered a key factor in terms of the policy context to be accountability. I use the following definition of accountability:

> . . . a condition in which individual role holders are liable to review and the application of sanctions if their actions fail to satisfy those with whom they are in an accountability relationship (Kogan, 1986, p. 86)

The culture in schools, as a consequence of national accountability, has been characterized in terms of *performativity*, for which I used the following definition:

> . . . a technology, a culture and a mode of regulation that employs judgements, comparisons and displays as means of incentive, control, attrition and change – based on rewards and sanctions (both material and symbolic). The performances (of individual subjects or organizations) serve as measures of productivity or output, or displays of 'quality', or 'moments' of promotion or inspection (Ball, 2003, p. 159).

I contend that accountability has the potential to influence school culture and classroom practice through *performativity*. Research seems to support this view. Although there have been no large-scale investigations of the effects accountability on school cultures, there have been a number of case studies of schools in challenging accountability contexts. Studies have found that there is a normalising effect on teaching as a result of "constant surveillance" and teachers "learning to 'play the game' " (Perryman, 2006, pp. 158-159). Staff unite ". . . in a game which presents the school in its best light" (Perryman, 2009, p. 620). Repeated observation by school leadership was used to normalise practice to perceived OfSTED models (Hall and Noyes, 2009, pp. 851-852). Perryman, Ball, Maguire, and Braun (2011) for example, investigated how the outcomes of OfSTED inspections influenced the culture of schools. In particular, there was on an influence on the character of professional development experienced in schools; the aim in schools was to implement approaches that were perceived to be valued by inspectors. Overall the accountability culture influenced the focus of professional development.

The normalising effect of constant surveillance and 'playing the game' is likely to result in traditional teacher-centred teaching. In support of this argument I refer you to my discussion of *the ubiquity of teacher-centred teaching* (p. 49). Increased pressures and attempts to normalise practice are likely to produce traditional teaching as a relatively 'safe' and historically proven set of performances and practices.

Increasingly OfSTED judgements have been based on a schools' examination results rather than teaching and learning based on classroom observation. This was a result of the introduction of 'short notice' inspections

in 2005 which focussed on management and systems, drawing on schools' self-evaluations. It is likely that a school with lower than expected results will want to focus on improving results, in the short term, rather than focus on developing the teaching of problem solving. Therefore, I considered schools' performance, as judged by OfSTED and in terms of examination results, as an important component of *coherence*.

As Krainer (2006) pointed out, *community* is also an important aspect and one in which I believed related strongly to the notion of *coherence*. This relates to two other characteristics of effective PD, those of *leadership* and *collective participation*. In this sense, coherence, in terms of community, concerns the way in which the PD might fit in with a department's culture. There has been limited previous research in this area so my investigation of this was exploratory. However, I was interested in how individuals in mathematics departments worked together, the character of department leadership and collective motivation, interests and perspectives.

Finally, I considered how the PD coheres with school-level strategy. As Pedder et al. (2008) pointed out schools rarely, if at all, evaluate their PD critically. Therefore I wanted to see how the PD fitted in with school-level plans and strategy: how embedded that PD was in the culture and aims of the school. Was it seen as a bolt-on activity or was it seen by school leadership as a fundamental part of the school's improvement programme? The way in which it was evaluated by the school would give some indication of where the PD was on this continuum.

Informed by professional development contextual theory (Cooney and Krainer, 1996; Krainer, 2006; Llinares and Krainer, 2006), I derived a hierarchical coherence/contextual framework shown in Table 3.1. The idea of *coherence* can be considered from the perspective of *social learning theory*. In particular, it is an expression of *reciprocal triadic determinism*, in which practices (behaviours) are influenced by the social setting (environment) and vice-versa. The individual is both affected by and contributes to this relationship. This is the reciprocal relationship I discussed in Section 3.2.2 (p. 40). In schools, I believe, this system comes into equilibrium for the reasons suggested by Cuban (1993), Stigler and Hiebert (1999) and Leinhardt (1988): the demands of the work of teaching, the institutional constraints means that routinized heuristically-formed practices prevail and are sustained through observational learning.

If the PD does not cohere to the equilibrated context, teachers will need to be efficacious in order to implement new ideas. In other words, they will need to believe that the suggested approach will work in their classrooms. The less the PD coheres, the more efficacious individuals will need to be. If the PD suggests approaches that are radically different, then teachers will need greater levels of efficacy to implement the ideas and approaches.

This relates coherence with practice, what about policy and culture? To explain this I consider the sources of self-efficacy as developed by Bandura (1977, 1986, 1997). The four sources of self-efficacy are *mastery experi-*

Table 3.1: Hierarchical coherence/contextual framework.

Contextual level or field	Description	Indicators used in this research
External	Curriculum, assessment, accountability and education policy.	*Contextual coherence* where I considered the accountability context.
School-level	The extent to which the school integrates the PD into the school improvement and strategic plan. The level of support in terms of resources. The extent to which the school evaluates the PD.	*PD integration with school aims.*
Dept.-level	For example, department culture, leadership style and collaborative culture.	*PD leadership style & department culture.*

ence, *vicarious experience*, *verbal persuasion* and *physiological and affective* states (these I introduced in Section 3.2.3, p. 43). Efficacy can be developed through successful implementation, through observing others implement ideas successfully, more weakly through persuasion and encouragement—efficacy is diminished by stress, being upset, tired and ill. In a supportive and collegiate environment teachers are likely to be comfortable implementing new approaches by developing self-efficacy through verbal persuasion and vicariously. In a high-stakes and pressurised environment, where school culture becomes led by accountability, teachers' efficacy can be undermined as a result of the negative effects of stress.

3.4 Research questions

To conclude this chapter, I introduce the research questions. These were developed from starting points offered by the funders and based on the analysis of the materials in the previous chapter and the conceptual framework developed in this chapter. I briefly explain how I interpreted these based on the development of my conceptual framework.

1. **How do teachers use the professional development materials: what do they attend to and why?**

   I considered the main part of this question at two levels—how departments used the PD and the extent to which they were implemented in a way consistent with the design intentions. This reflected the

coherence characteristic above. I also considered this in terms of individual teachers from the perspective of observational learning and self-efficacy. This two-level analysis reflects the *situative* approach I identified above. As a result of my consideration of coherence and context I looked into each school's context in relation to accountability, I considered how well the PD complemented and was integrated into school and department strategy.

2. **How do teachers' self-efficacy beliefs and practices evolve?**

   I considered here specifically changes in self-efficacy both qualitatively and quantitatively. I carried out a mixed-methods analysis of changes in practices, this I explain in more detail in the next chapter.

3. **Which practices do teachers find easiest or most difficult to adopt?**

   In this question, I am addressing how teachers implement or integrate the ideas from the PD into to their teaching. It is related to the question above and how teachers' practices evolve. Here, I am interested in the processes of implementation. This was testing out the theory of practice that I set out in this chapter where I explained, using *social learning theory* and how practices tend to traditional and teacher-centred models. Here I considered what the trajectory of change might be. It is also related to the observational learning process and to developing (or not) self-efficacy in the suggested approach.

3.5 Summary

In this chapter, I began with a review of research into professional learning theory. In this I showed that mathematics teacher professional development research is characterized by small-scale studies and that there is a lack of overarching theory with which to compare and synthesise results and findings. I introduced *social learning theory* as new theoretical approach and one that has the potential to provide a more general overarching theory. I described this theory in detail and justified its appropriateness. Following this, I used *social learning theory* to explain why teaching is predominantly teacher-centred in secondary mathematics classrooms in England. I described a model of professional learning based on *social learning theory* and explained the processes and constraints in changing teaching practices from a teacher-centred orthodoxy.

I integrated the professional development effectiveness factors derived in the previous chapter and interpreted these empirically-derived factors from a *social learning theory* perspective. I concluded with the research questions. In the next chapter I describe the methods used in this research.

Chapter 4

Methods and methodology

In this chapter, I describe the research design: the methods used and supporting methodology. In the previous chapter, I presented the research questions and an elaboration of those questions based on my development of a conceptual framework using *social learning theory*. Integrated into this were the characteristics of effective PD derived from previous research which I introduced in Chapter 2.

The research design was guided by the following research questions:

1. How do teachers use the professional development materials: what do they attend to and why?
2. How do teachers' self-efficacy beliefs and practices evolve?
3. Which practices do teachers find easiest or most difficult to adopt?

I begin with an overview of the research design and describe the case selection and sampling approach.

4.1 Overview

I investigated three mathematics departments with all teachers in each department involved in the PD. I used an *embedded multiple-case study* design (Yin, 2009). This allowed me to make comparisons between different contexts and also provided an appropriate sample size for the quantitative analysis. Based on the experience I had in a pilot study, I believed this would be a manageable project size for a single researcher.

The units of analysis were the mathematics departments and the embedded cases were individual teachers in the departments. I observed three teachers in each department through the course of the PD programme, to explore how their efficacy beliefs, perspectives on teaching and actual teaching changed over the course of the programme. After discussion with the Shell Centre, I agreed that I would observe two PD modules over two

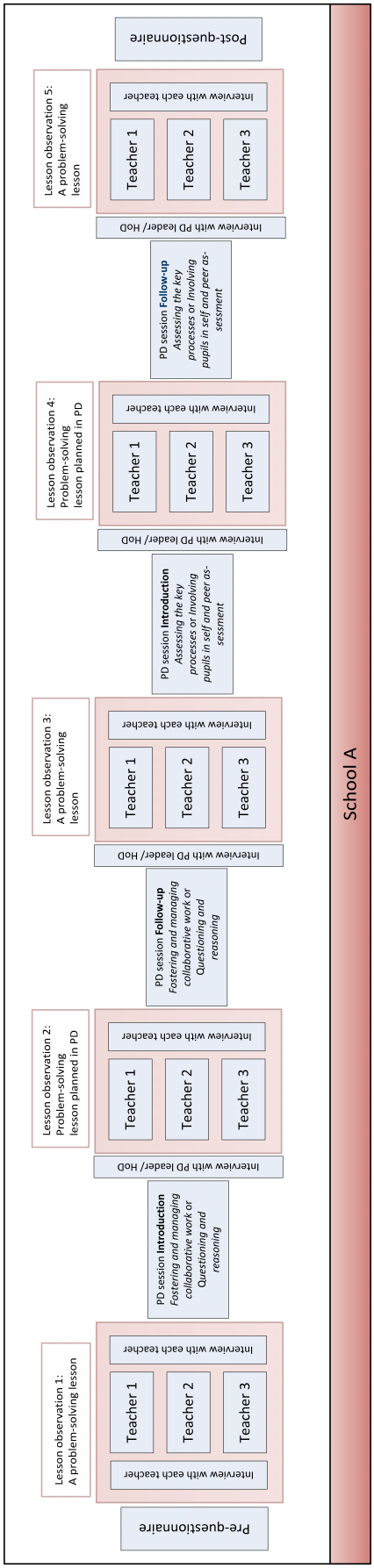


Figure 4.1: Data-collection approach in a single school.

terms. I devised a PD and data collection schedule which is shown in Figure 4.1 (p. 63). This involved cycles of PD and lesson observation. In order to focus on how teachers' developed in the teaching of problem solving, teachers were asked to teach problem solving lessons in lesson 1, 3 and 5. The tasks and activities were the choice of individual teachers in these lessons. In lessons 2 and 4, it was expected that teachers would teach the lesson planned in the PD introductory session preceding it. Teachers would also be observed with the same class through the project.

4.2 Selection of schools and teachers

I approached schools that were part of the initial teacher education partnership at the School of Education, University of Nottingham. I contacted eighty-six secondary schools and invited them to participate in the project. The head of mathematics in each of these schools was sent a letter about the project and an information leaflet each mathematics department was offered £500 to take part in the study. Twelve schools expressed an interest and after an initial discussion seven schools remained interested in taking part.

A meeting was arranged with each of the schools, where the project was explained in detail. Four schools were recruited and were self-selected (a summary of the schools is shown in Table 4.1, p. 65). Hilltown, on account of an unfavourable OfSTED inspection, did not complete the whole PD programme. Since one aspect of this research was concerned with how the PD coheres with contextual issues, I have included data from this school in the next chapter.

While there are potential issues in cases being self-selecting, this research is exploratory in the sense that I am bringing new theory to the professional learning context. Therefore this selection approach is appropriate to this study; sampling bias will not impinge on the issues being addressed with the range of research questions that I have. If for example I was attempting to evaluate the effects of the PD I would have needed an alternative sampling strategy—one that would have been more representative. Here my research questions were to do with how things work and happen, therefore it was appropriate to examine these in different settings without being overly concerned about self-selection. This *convenience* (Bryman, 2008; Cohen, Manion, and Morrison, 2007) approach to sampling was not intended to be representative or for the purpose of statistical generalisation.

Furthermore, this research was undertaken as six discrete but interconnected studies. Each of these used different case selection and sampling strategies. Additionally there were multiple approaches to triangulation within and between the six studies.

A similar approach was taken with the selection of teachers to take part

Table 4.1: School characteristics.

School	Age range (years)	Number of students	Location and context
Barrington Community College	14–18	1170	Large suburban village on the edge of a city
Boxton Academy	11–18	1490	Rural—between two large market towns
Hilltown School	11–16	750	Rural
Norman Fletcher School	11–18	2000	Suburban village on the edge of a city

in observations through the project. While it had been intended that teachers would be at different career stages and there would be approximately equal numbers of men and women overall, the final selection was heavily influenced by availability of suitable volunteers. Three teachers were selected in each school. I decided that these teachers would be observed with the same class through the project. Again, because this research is exploratory, I justify the appropriateness of the sampling approach as I did with the schools.

I begin with an overview of the methods within which I also reflect on the methodological approach. This is followed by a detailed account of the methods used in each study.

4.3 Methods

The overall strategy was an *embedded mixed-methods multiple-case study design*. The three *cases* were the mathematics departments and the *embedded cases* were individual teachers.

Bryman (2008) suggests a *case* is often considered as a location and *case study* implies intensive examination of that setting. Stake (2008) argues that *cases* in education are people and programmes. "We are interested in them for both their uniqueness and commonality. We seek to understand them. We would like to hear their stories" (Stake, 2008, p. 1). This is largely consistent with Yin (2009):

> [T]he distinctive need for case studies arises out of the desire to understand complex social phenomena. In brief, the case study method allows investigators to retain the holistic and meaningful characteristics of real-life events—such as individual life cy-

> cles, small group behavior, organizational and managerial processes, neighborhood change, school performance, international relations, and the maturation of industries (Yin, 2009, p. 4).

The multiple-case study, while more demanding of time and resources, can often provide more compelling and more robust evidence (Yin, 2009, loc. 1269). Although, as Yin (2009) points out, the rationale for the multiple-case study can be quite different to the single case study. The single case study is often seeking the unusual or unique case.

Implicit in this design was a triangulated approach. There is a more orthodox data triangulation which draws on mixed-methods—quantitative and qualitative methods. In addition, I utilised one of Denzin's (1970, cited in Cohen et al., 2011, p. 196) broader triangulation methods, that of *combined levels of triangulation*. This involves multiple levels of analysis using three principal levels: the individual, the interactive (the group) and the level of 'collectivities' (organisational, societal and cultural) (p. 196). At the outset of this research I was interested in professional learning by considering multiple levels of analysis. The multi-level design reflects Borko's (2004) proposed *situative* approach described in Chapter 3 (Section 3.2.2, p. 40). This approach, at a methodological level, made a contribution to the validity of the claims. While *data triangulation* is articulated in the results chapters, I address *combined levels of triangulation* in the discussion in Chapter 8, where I make comparisons and contrasts between studies.

The first two aspects of the research methods, presented in the following sections, are at the level of the mathematics departments. I begin with a description of my approach to the analysis of each department's context (Study 1, Section 4.3.1), followed by a description of the methods used to investigate how the PD was used by each department (Study 2, Section 4.3.2). These aspects addressed the question *how do teachers use the professional development materials?*—at the level of the department.

Following this, I consider *embedded cases* i.e. teachers' use of the PD. I begin with the description of an explanatory case study of what teachers attended to in PD sessions (Study 3, Section 4.3.4), this addressed the latter part of the question, *how do teachers use the professional development materials:* ***what do they attend to and why?*** I move on to an explanatory study of individual teacher's use of the PD materials in a lesson (Study 4, Section 4.3.5). This addresses—with teachers as the unit of analysis—the question, *how do teachers use the professional development materials?*

I then describe the quasi-experimental approach to the quantitative investigation of changes in teacher's self-efficacy beliefs and changes in their self-reported practices (Study 5, Section 4.3.6). This addresses the question, *how do teachers' self-efficacy beliefs and practices evolve?* Finally I describe the data collection and analysis for the qualitative investigation of changes in self-efficacy, teachers' perspectives and beliefs, and changes in their practices (Study 6, Section 4.3.7). This addressed the previous

question and the question, *which practices do teachers find easiest or most difficult to adopt?*

The overall analytic strategy draws on Yin's (2009) idea of *analytic generalisation*. This research (and each aspect) is generalised to *social learning theory*.

4.3.1 Study 1: Contextual factors

I identified how the characteristic of *coherence* was important, first in Chapter 2, and then I integrated it with the conceptual framework I developed in the Chapter 3. My interpretation of *coherence* was the extent to which the PD is consistent with a range of contextual and cultural factors. Within these, I included national policy—particularly the accountability culture—and school aims, culture and the department culture. I was interested in characterising the climate and conditions within which the PD was implemented. My aims were to provide a descriptive yet rigorous account of each school and to identify key contextual factors that influenced the way the PD was implemented.

This related to the question, *how do teachers use the professional development materials?* This question, as I discussed in the previous chapter, I considered at two-levels—at the level of the mathematics department—so, how did the department use the materials? And, at the level of the individual teacher. In this aspect of the research, I was concerned with how contextual factors had a bearing on the former.

I collected a range of data on each school's context and character in order to make preliminary assessments about how the PD would cohere with the school's context, culture, practices and aims. At the outset, I wanted to get a sense of the conditions under which the school was operating and begin to hypothesise the effects of these conditions on how the PD would be implemented. I also began to identify characteristics of the school and department culture.

School data were collected about the schools' context: the size, location, pupil population, history, examination results and OfSTED inspections reports. I used examination results and OfSTED judgements as principal characteristics of school and department context, since these drove the strategy and aims of each of the schools, as was consistent with the observations made by Perryman et al. (2011). The other characteristics provided general descriptions of schools' contexts and character and contributed to me getting a richer understanding of each school, although they were secondary to accountability data i.e. examination results and OfSTED reports.

I used data collected on my first visit to each school to develop a picture of the school, department and its culture. These data were mostly drawn from initial interviews with the head of department at each school. In the initial interviews, we discussed the project information, the practicalities of the project and I asked a series of questions about the school, the

mathematics department, the teachers in the departments, the challenges the school and department faced and the motivations about wanting to participate in the PD.

The initial interviews were audio-recorded and selectively transcribed. From these data, I wrote a detailed case description for each department with a description of its context, department culture, school and department aims and the head of department's leadership approach. The interpretive narrative accounts of each school and department are presented Chapter 5 (Section 5.2, p. 109).

In the case descriptions, I included the following: my impressions of the head of the department; contextual factors (as perceived by the head of department); some department background (where it appeared relevant); a summary list of teachers in the department; a description of the character of the department (again, as perceived by the head of department); my analysis and interpretations and also my judgement as to the extent to which the school had integrated the PD into its strategy and operations.

I tested and developed these descriptions as I visited the schools through the project and through observations and interviews with staff. Field notes were also made relating to the way in which teachers in the department worked together and the leadership style of the head of the department. In the schools I also observed and recorded data relating to the schools' strategic approach, context and issues that may have influenced the implementation of the PD. I became quite familiar with each school as I spent up to 15 days over two-terms in each school.

The validity of these findings is based on my familiarity with each school and a progressive refinement of the findings through the project.

4.3.2 Study 2: How departments used the PD: *fidelity* with the PD design

Having considered preliminary indications of *coherence*, I developed a further empirical analysis of how the PD was used. This built on the analysis introduced in the previous section; it offered an alternative analysis of coherence effects.

My assumption was, based on the research undertaken by Desimone et al. (2002), that the more closely the PD cohered with school context, culture, policy, practice and aims; the more likely it was that the PD would be used in the way intended by the designers.

I developed a *fidelity* measure to give an indication of the extent to which each part of all four PD sessions was implemented consistently with the PD documentation. If the *fidelity* score was high then the PD was used as designed and I had some evidence that the PD cohered with the school and department context and culture i.e. the PD was relevant. This is not, by any means, a precise measure and there may be many reasons why *fidelity* might be low. However, I assumed that these results combined with the qualitative contextual analysis, described in the previous

section, provided a basis for making an overall judgement of coherence. It provided a means by which the observation of the PD could be analysed systematically in terms of the PD coherence.

Before explaining the *fidelity* measure, I describe the guidance given to heads of departments in the way they should use the PD. They were given the following instructions which were communicated verbally at the pre-project meeting and also included in the project handbook:

> Each session should take about one hour and all the materials, including suggested timings are included in the module handbooks and can be accessed online (www.bowland.org.uk). While there is choice and flexibility as to how the sessions can run, it is important that whoever leads the session uses the range of materials including videos and handouts and follows the designed structure. In reality there is more material included in the modules than can be fitted into a one hour session. Some choices and decisions have to be made, if the professional development leader is unsure then they should contact us when planning the session to discuss the module plan (Project Handbook, p. 9).

With this I attempted to guide PD leaders to understanding the aims and ideas of the PD and remain consistent with these, even though they would have to make some decisions about the material that would or would not be used. The expectation was that they would include all the parts of the PD which included a series of 5-, 10-, 15- or 20-minute 'activities'.

All PD sessions were observed and a video recording made. My analysis began by writing a chronologically-organised, activity-by-activity description of each department's participation in the PD as I watched the video-recordings of the PD sessions. I summarised key events and created a summary of each activity in each session. An example of this is shown in Tables 4.2–4.4 (pp. 70–72). I then conducted a *fidelity* analysis on each activity.

The *fidelity* of the PD sessions was assessed using a scoring approach. Each activity was given a *fidelity score* to indicate the extent to which the activity was completed as suggested in the PD materials. The possible scores were, 3, 2, 1 or 0. The criteria for each were as follows: a score of 3 indicated that the activity had been carried out in a way consistent with the ideas presented in the PD materials, the Bowland Player or module handbook. A score of 2 suggested some elements had been modified and aspects had been omitted, or the focus had some inconsistencies with the ideas suggested, although similar intentions were retained. A score of 1 indicated the activity was done, but it appeared to be inconsistent or different to the suggested approach and a score of 0 was given where the activity had not been done at all.

Table 4.2: Example of PD observations, Boxton Academy, Autumn term, *Fostering and Managing Collaborative Work*, *Introductory* session, part 1.

Activity	Suggested time	Time taken	Aim of activity	Observation summary
Intro	NA	1′	**The importance of discussion:** To present the aims of the session and explain and clarify the importance of discussion.	Amy introduces the module by presenting a list of the session activities. She does not present or use the PD materials to provide an overview of or give any reference to the importance of discussion in teaching problem-solving.
1	10′	4′	**Experience a mathematical discussion:** Teachers are expected to work on a task and to think about their own discussion when collaboratively problem-solving.	Teachers work in groups on the *How many teachers in the UK?* problem (see handout 1, Figure 2.4, p. 20). Towards the end of the activity, Amy distributes all the session handouts. This activity is completed quickly.
2	10′	4′30″	**Reflect on your discussion:** Teachers are encouraged to analyse their discussion using frameworks provided in the PD.	Amy prompts her colleagues to look at handout 2, *Recognising helpful and unhelpful talk* (see Figure 2.4, p. 20). The whole department get involved in the discussion and talk about the way they discussed the problem. There is consensus that much of what they were doing was 'cumulative' talk, building on each others' ideas.

Table 4.3: Example of PD observations, Boxton Academy, Autumn term, *Fostering and Managing Collaborative Work*, *Introductory* session, part 2.

Activity	Suggested time	Time taken	Aim of the activity	Observation summary
3	20′	18′	**Observe a discussion lesson:** To observe video clips of lessons the feature student discussion and collaboration when working on problem-solving tasks. The prompt questions are: • How does the teacher introduce the problem? • What different approaches are being used by pupils? • How does the teacher help pupils to discuss productively? • Can you characterize the types of talk they are using?	Amy introduces the video and reads out the questions that are presented in the materials. They watch the longer extract of Eve's lesson. There are a range of responses from members of the department. Mary says she likes the way the teacher encourages students to think about the problem individually—she says that when they began the discussion they had some ideas. This appears to be an observation about the lesson structure. Phil comments on the use of resources, he says he liked the use of small whiteboards, so they could change their ideas. Tony says he likes the way the teacher asks the pupils, 'why?' and 'why do you think that?' Nigel notices how Eve gave the students very little direction. Amy observes that in order that students have opportunity to develop their collaborative and discussion skills, the level of mathematics in the tasks has to be relatively low. They watch the last part of Eve's lesson.

Table 4.4: Example of PD observations, Boxton Academy, Autumn term, *Fostering and Managing Collaborative Work*, *Introductory* session, part 3.

Activity	Suggested time	Time taken	Aim of the activity	Observation summary
4	10′	5′30″	**Discuss implications for teaching:** This activity is intended to provide practical support for teachers to support student discussion. The principle underlying the activity is that students need to be taught how to discuss.	They concentrate on handout 3, *Ten ground rules for pupil-pupil discussion* (see Figure 2.5, p. 21). Amy suggests that they think about what rules they want as-a-department. There is still collective interest in finding out how many teachers there are in the UK. As a group, they discuss the usefulness of the ten ground rules. There is discussion about whether agreement should be reached within student collaborative groups. Tony asks if there are any of the rules that they are all agree should be used. They then decide which rules they will use. Amy considers group roles and assigning different roles within student groups. Mary suggests that students come up with rules, and this is discussed.
5	10′	10′	**Plan a lesson using one of the problems:**	Amy refers to handout 1, *Problems for discussion.* She suggests that everyone choose a problem to do with a class and work in twos, threes or fours to plan the lesson. They begin to think about the lesson design as a department, 'shall we get them to think about it on their own first?' Christine is concerned about her low-ability group accessing the task. They discuss group sizes and their experiences, whether they should choose the group or let students do this. Effort is made to steer toward agreement and consensus across the department.
Totals	60′	43′		

To illustrate the coding process, I draw on an example of an activity, from the first PD session at Boxton: *activity 1*, which is described in the descriptive summary in Table 4.2 (p. 70). This was given a score of 2 because the time for the activity was reduced to half that suggested (see Table 4.2) and the activity videos were not used. In other examples, a score of 2 would be awarded where, for example, teacher discussion drifted away from the aims and ideas suggested in the materials. An example of a score of 1 was in activity 3 of the introductory session of the second PD module at Boxton. None of the activity materials were used and the discussion was only partially related to the aims of the PD and the activity.

The *fidelity scores* for each activity were weighted based on the time suggested in the PD materials for that activity and a total determined for each session in each school.

Reliability was assessed by considering the initial results in comparison with the case descriptions: calibrating and making adjustments as necessary, in order that the *fidelity scores* appeared consistent with the qualitative data i.e. the descriptive analysis of the PD sessions in Tables 4.2–4.4. The results are presented in Chapter 5 (see Table 5.8, p. 118). The total weighted *fidelity scores* for each PD session is illustrated graphically in Figure 5.2 (p. 119).

4.3.3 Synthesising the contextual analysis with the fidelity analysis

Having carried out the two previous analyses, I summarised the contextual data in order that I could make some cross case analysis of the effects of context on PD coherence. I summarised the contextual data into four overarching characteristics: *contextual coherence*, *PD integration with school aims*, *department leadership style* and *department culture*. For the first two characteristics I summarised the context as *high coherence*, *moderate coherence* and *low coherence*.

In respect to *contextual coherence*, I considered the schools' examination results and OfSTED judgements. I summarised it to be a 'high' contextual coherence when the school's results were good and there was a positive trend. I gave a *moderate* summary if the schools results were about the national average and the OfSTED judgement in the most recent report was 'good'. I gave 'low' to contexts that were more demanding than this.

I used a similar *high*, *moderate* and *low* coherence descriptor to summarise the extent to which the PD was integrated into the school. I used two criteria, the first was whether the PD was integrated into the school development plan and second, whether the PD had been evaluated. No school met both criteria. If the school had integrated the PD into its development plan without evaluating it I summarised it has a 'moderate' coherence. If the schools had done less than this I counted the PD integration as 'low'.

At department level, I looked at the PD leadership and used one or two single word descriptors to summarise the leadership. These were derived

through using an open-coding qualitative analysis of the data collected about departments:

- *Informal* – The head of department has a relaxed and easing going style, discusses decisions with members of the department and shares leadership and management tasks.
- *Participatory* – The head of department is involved in activities taking place in the department, they lead from amongst the department.
- *Authoritarian* – They have a strong sense of authority, they make decisions without always consulting the department.
- *Crisis* – There is no leadership function or it is in a state of rapid transition.

I used a similar approach in summarising the department culture:

- *Cooperative* – Individual teachers share resources and offer mutual support.
- *Team-spirited* – A culture in which teachers are keen to work together and develop consensus.
- *Individual* – Teachers work individually and behind closed classroom doors.
- *Collaborative* – Teachers develop lessons together and observe each other teach.

Finally I summarised the longitudinal fidelity profile as declining or stable (remained roughly the same through the project) as a *fidelity profile*.

From the summaries of each aspect of context and coherence, I explained the fidelity profile for each school in terms of the contextual factors and the extent to which each contributed. I was therefore able to explain how the PD was used in each department. The results of this analysis are presented in Section 5.4 (p. 122).

The intention of the approach I adopted in this synthesis was not simply to reduce contextual and coherence characteristics to overly reductive labels. My aim here is to allow these summaries to offer a conceptual guide, to enable the reader to quickly get a sense of the richer cross case analysis and discussion. The labelling and categorisation is not a conclusion but a presentational device.

To illustrate this, a school with a high department coherence characteristic and low school characteristic can be compared with a school with different coherence characteristics. In the readers mind this is a simplified overview, which is a first opportunity to engage with the in-depth case analyses. Importantly, it is the richer accounts of context that I have used in the formation of conclusions.

4.3.4 Study 3: How teachers used the PD materials in sessions

This aspect of the research was intended to address the adjunct to the research question, *how do teachers use the professional development materials: what do they attend to and why?* I was interested in what teachers attended to in the PD and to understand why particular aspects were important. From an observational learning perspective, I wanted to understand the processes by which teachers observed and interpreted the content of the materials. Initially, the funders, I believed, had conceived this question, '*what do teachers attend to and why?*' as a study of what teachers noticed in the PD. I, in introducing *social learning theory*, was interested, not just in the aspects of the PD to which teachers' attention was drawn and the aspects they noticed, but in the processes of observation and noticing. *Social learning theory* gave this analysis a broader conceptual range, bridging noticing and observation to action.

Given that I had three case study mathematics departments who completed two PD modules (that was four PD sessions: an *introductory* and *follow-up* session for each module), I had to decide on an approach that would reveal most about observational processes. The PD sessions had been observed and video-recordings made of each session, these were used as a data source for this study. They exhibited teachers' reactions to and discussions about the approach suggested in the PD. Teachers, in these sessions, made comments and provided reactions to the suggested approach.

I used data from *introductory* sessions, since this preceded teachers' attempts to implement the suggested approaches in the *into-the-classroom* phase of the PD. It provided me with an illustration of what teachers were doing in the context of a PD session as they thought about implementing the approach in a lesson. In the *follow-up* sessions, teachers' discussions involved reflecting on their experience. I wanted their discussion to feature some aspect of what they thought about implementing the ideas in their classrooms. So I focussed on the *introductory* sessions.

I identified those parts of the *introductory* sessions that revealed most about what teachers attended to and noticed in the PD. To do this, data reduction and preliminary analysis was carried out for each *introductory* session. A descriptive summary was produced for each session which provided a summary of each activity through the PD session. In Section 4.3.2 (p. 68), I described the analysis of *fidelity* which used the descriptive summaries of all PD sessions. An example is shown in Tables 4.2, 4.3 and 4.4 (pp. 70–72). This example is a summary of the *Fostering and Managing Collaborative Work* introductory session at Boxton.

It can be seen how *activity 3* (see Table 4.3, p. 71) represents a major portion of the PD session, it took 18 minutes of the 43-minute session. Just over half the activity involved observing video clips of the model lesson, which featured a class working on the *How many teachers in the UK?* problem. Approximately 5 minutes of the activity featured a discussion

between teachers about the lesson they observed. There were similar activities in the first *introductory* sessions at Barrington and Norman Fletcher. I therefore analysed teachers' reaction, comments and discussion about an example of the ideas in the PD illustrated in a video of a lesson using the 'observe a lesson' activity.

Although, I considered analysing the 'observe a lesson' activities in each of the three schools, I used a single case for this. At Barrington the activity lasted 23 minutes, but the discussion was brief and featured just three of the seven teachers. At Norman Fletcher, they spent 18 minutes on this activity, having watched 6 minutes of the 12-minute example lesson. The discussion was led by the head of department. Since the department was large (15 teachers) it was not possible to get a complete audio recording of all teachers' contribution to the discussion. The 'observe a lesson' activity at Boxton was a concise and vivid illustration of the discussions I had observed in the three PD sessions; I therefore used the *introductory* PD session at Boxton as an *intensity sample*. This type of *purposive sampling* involves identifying a case with a particular set of characteristics (Cohen et al., 2011). I sought from my data set, an example that "provides clear examples of the issue in question" (Cohen et al., 2011, p. 157). The 'observe a lesson' activity in the first *introductory* session at Boxton met these criteria. The characteristics I sought were that the data included discussion between teachers about the video lesson and that that the data was suitable for analysis.

The discussion was transcribed and is presented in the results in Chapter 6 (Section 6.1, p. 128).

The methodological approach was an *explanatory* case study, where I sought explanation and causes for the phenomena observed. I used a propositional approach to analysis, this involved hypothesising a theoretical position and using this to explicate the observations made by teachers in their discussion. I used *observational learning theory* and its wider conceptual context of *social learning theory* as explanatory theory. In using this approach it is necessary to consider rival explanations and theory: these examinations are considered in the results in Chapter 6 (Section 6.1, p. 134).

The validity of this aspect of the study was dependent on the validity of theory and the quality of the inferences made about the comments and discussion between teachers. This is strengthened by using a propositional approach and examining rival explanation and theory. However, of all the components of this research, this area is the more tentative and would benefit from further study. In spite of this, the analysis offers valuable insights into the way teachers interacted with the PD, attend to aspects of it, and evaluated it.

4.3.5 Study 4: How teachers used the PD materials: teacher case studies

In this part of the study, I addressed the research question, *how do teachers use the professional development materials?* and focussed on how teachers implemented the ideas suggested in the PD. It was related to the study of a group of teachers I described in the previous section, but goes further by looking at the way in which teachers implemented the ideas. The previous analysis focussed on observational processes, as teachers engaged with the PD's suggested approach portrayed in edited video of example lessons. In this part of the research, I was interested in how teachers implemented the PD. I continued to attribute learning to attentional processes of observational learning, but I was interested in how the models within the PD materials were interpreted, adapted and implemented. Moreover, I was interested in the reasons teachers adapted the suggested approach, where they had done so.

In this part of the study I was interested in the *production* and *motivational* processes of observational learning. That is, how teachers turned the ideas they had observed in the PD into lessons and the reasons for their decisions.

I decided on a case study approach for this analysis, my choice was informed by Yin's (2009) guidance on methodology selection (kindle edition location (loc.) 421). If the research question involves a 'how?' question then it is likely that it is an *explanatory* study. Yin suggested, for this kind of study, the options are *experimental*, *historical* or *case study* methodologies. Since I was dealing with contemporary events and that I would not be able to "manipulate behavior directly, precisely or systematically" (loc. 485), I ruled out *historical* and *experimental* studies and chose a case study approach with individual teachers as units of analysis.

I selected cases based on a *quota sampling* approach (Cohen et al., 2011, p. 156): one teacher from each school. Within schools, I used *purposive sampling* for selection of cases. This involved the selection of particular cases with certain attributes. My purposive sampling was also informed by an *intensity sampling* approach "...in which the sample provides clear examples of the issue in question" (p. 157).

In order to provide "clear examples", I selected teachers who taught high-attaining groups through the project. I was aware (from my own experience and observations in the pilot study) that teachers who participated in the observations found implementing the suggested student-centred problem-solving approaches challenging. They found it more challenging with lower-attaining groups. Consistent with Boaler's (1997) analysis, I found these groups often included students with low-levels of mathematical confidence and negative attitudes to mathematics. In order to investigate how teachers used the materials I decided to try and minimise this effect and focus on the way in which teachers used the materials with higher-attaining groups.

This is not to say that I do not believe that all students should have the opportunity to engage in problem solving. However, I had particular aims in this research that was to understand how teachers learnt new approaches. My view was that if I could improve the quality of professional development as a consequence of this research, I could focus on the particular issues apparent in the teaching of low-confidence, low-attaining learners in the future.

In each school there was at least one teacher, who had agreed to participate in the video study and who taught a 'top set'. At Barrington there were two teachers who taught year 11 set 1 classes, Barry and Imran. Imran was selected for this analysis as Barry (I believed) was different to the other teachers involved in the study. I considered him to be confident and he had a particularly strong relationship with his class. My judgement was that he was much more at ease with student-centred approaches than the other participating teachers. I decided, therefore, to focus on Imran, since his experience I considered more representative of the kinds of challenges teachers had in incorporating student-centred teaching into their teaching. This decision was consistent with my *intensity* sampling approach.

In the project guidance, I asked heads of departments to ensure the teachers I observed worked with the same year 8 or year 9 class for the whole project. Barrington was a 14–19 school with year 10 and 11s only. In my initial discussions with Deborah, the head of department, we agreed that they could participate with year 10 classes. However, when it came to finding teachers to participate in observations, Barry and Imran wanted to work with year 11 classes. To ensure I had a sufficient number of participants I allowed this. I had expected that they would adapt tasks to provide an appropriate level of demand and challenge. However, Imran chose to use the tasks in the PD materials with a high-attaining year 11 class. This in the end, I believe, was not detrimental to the research.

The three teachers selected for the case studies were: Imran (Barrington), David (Boxton) and Cath (Norman Fletcher).

This analysis focussed on how teachers took the ideas suggested in the PD sessions—described in print materials and illustrated in video—and translated them into classroom practice. I decided to analyse the teachers' first attempt to teach using the ideas suggested in the PD. This was the lesson after the first *introductory* session of the first PD module—the first *into-the-classroom* lesson. In this lesson, teachers were trying out a lesson they had planned in the PD session using the ideas suggested in the PD.

There were two reasons for using the first *into-the-classroom* lesson. The first was a fatigue effect: departments implemented the PD less consistently with the design intentions during the second modules. The results of my analysis of this are presented in the next chapter (see Section 5.3, p. 117). Using the *intensity* approach I wanted to maximise the issue under investigation.

The second reason was so that I could exploit the sequential development of interviews that I conducted with each teacher after each of the five

observed lessons. I elaborate on the data collection and analysis next.

I observed and video-recorded the lesson and carried out an interview with the teacher after the lesson. I carried out an analysis of the lesson using a lesson structure approach. A lesson structure is, "... the hierarchy or arrangement of episodes or passages of a lesson that are related yet have distinct features" (Watson and Evans, 2012, p. 89). This was developed in collaboration with the University of California, Berkeley as part of a structured observation scheme (see, Schoenfeld, 2013). It also built on previous work on lesson observation by the Shell Centre in the development of SCAN (Systematic Classroom Analysis Notation) (Beeby, Burkhardt, and Fraser, 1979) and drew on the lesson structure approach developed by Clarke and collaborators (see, for example, Clarke, Mesiti, Jablonka, and Shimizu, 2006).

I describe the approach in more detail next.

4.3.5.1 Lesson analysis

This analysis involved dividing the lesson into a series of *episodes*, where episodes were defined as "... periods of time during which the class is engaged in one relatively coherent type of classroom activity" (Schoenfeld, 2013, p. 5). The *episode* types I identified were:

- **Whole-class** *episodes* – the characteristic of this type of episode was that the teacher led the events and might include, for example, whole-class discussion. This type of episode was further classified as:
  - *Launch* – the teacher introducing a problem, task or activity.
  - *Teacher exposition* – a lecturing or explaining type of whole-class episode.
  - *Teacher directions* – the teacher is giving instructions about classroom organization or the way in which some activity should be undertaken.
- **Small group work** – students work in groups of two or more on a task or activity.
- **Student presentations** – students present their work to the whole class.
- **Individual work** – students working on their own on a problem.

A colour coding scheme was devised for this classification and is shown in Figure 4.2. As with other studies (Beeby et al., 1979; Clarke et al., 2006; Schoenfeld, 2013) the identification of episodes was found to be reasonably reliable without having to undergo more formal tests of inter-rater reliability.

Episode code	Description	Colour
N	Not coded	
W	Whole class	
W(L)	Launch	
W(E)	Exposition	
W(D)	Directions	
G	Small Group Work	
P	Student presentations	
I	Individual work	

Whole class: teacher led

Figure 4.2: Lesson structure: the coding used for the different types of episode in a lesson.

I made direct comparisons between the lesson structure of each teacher's *into-the-classroom* lesson and the lesson plan that was included in the PD materials and also illustrated in the video materials. This gave an indication and pictorial representation of how teachers adapted the ideas and approaches suggested in the PD.

However, I was not just looking at the adaptations teachers had made to the lesson structure. I also considered characteristics within the lesson that differed from the suggested approach. In the case of Imran's lesson, it was the way in which he used questioning, in David's lesson, it was the way in which he used group rôles in collaborative groupwork, whereas Cath made few adaptations overall.

I wanted to know why they had made adaptations (and why not) and what their perceptions of and motivations for the adaptations were. I was looking for an explanatory analysis of how teachers turned the ideas presented into classroom practice.

4.3.5.2 Teacher interviews

I found that a comparison of lesson structures with the suggested lesson plan was useful but insufficient in elaborating on how teachers used the PD materials and how they had adapted and implemented the PD into the classroom. I therefore used post lesson interview data to identify how teachers believed they had used the materials and their reasons. The interview that took place after the observed lesson provided some indication of what aspects of the PD and the lesson were important. However, the main source of perspective on teachers' use of the PD materials was taken from the series of interviews I conducted after the fourth round of interviews.

Each teacher was interviewed five times through the project, after each observed lesson, interview protocols were developed progressively. Cohen et al. (2007, p. 353) described a spectrum of interview types, ranging from *closed quantitative interviews* to *standardized open-ended interviews* to an *interview guide approach* to an *informal conversational interview*, each of these becoming less structured and less formal.

The initial interviews were of an informal conversational type, this gave me the chance to get to know each teacher and to put them at ease about the observation process. After the third round of interviews, I analysed the interview data from three teachers (one from each school) in order to develop an interview protocol for the fourth round of interviews. The protocol is shown in Figure 4.3. I used the fifth interview for respondent validation.

1. How did you find that lesson?
2. Describe the aspects of the PD that you used most in planning and doing that lesson.
    a. Why were they/was that more important than other things that you saw in the PD?
    b. Why did you think that was particularly important?
    c. Describe some of the aspects of the PD that you have seen that you have incorporated directly into this lesson.
3. Describe the way in which this lesson is different to the way you teach normally.
4. As a result of taking part in the PD what do you think has changed in the way you generally teach?
5. What are the most important aspects or features of the PD?
6. What are the challenges in teaching in the ways suggested in the PD?
7. In what ways, if any, has your views about mathematics or teaching mathematics changed as part being involved in the PD?
8. Have you noticed any changes in the way students approach problem-solving?

Figure 4.3: Post-lesson interview protocol.

This protocol was used for other aspects of the research and so the questions related to all the research questions. However it was particularly question 2 that had been developed to address this part of the research.

- Describe the aspects of the PD that you used most in planning and doing that lesson.
    - Why were they/was that more important than other things that you saw in the PD?
    - Why did you think that was particularly important?
    - Describe some of the aspects of the PD that you have seen that you have incorporated directly into this lesson.

I found that I had to be flexible in the way I used this protocol and adapted the questions in the actual interviews. An example of an interview transcript is included in Figure 4.4–4.7 (pp. 82–85). In this it can be seen how Imran did not explain how he used the PD materials in his answer to question 2 (Figure 4.4, p. 82). He revealed more about this as a result of questions I asked in the discussion relating to question 4 (Figure 4.6–4.7, pp. 84–85).

Post lesson interview with [redacted] 22-2-2013
Lesson 4

[Prior to interview [redacted] is reprimanding two students]

Q1. How do you think that went? How did you find that lesson, should I say?

[redacted] In all honesty, I was quite pleased with it. I thought …

I thought they were … they thought about the problem very well. We went through the problem for the last twenty minutes yesterday. The suggestions they were coming out with yesterday was quite positive, so I thought it was going to be a good lesson. I thought a lot of them, without being aware of those terminologies we use, were actually really thinking about how the responses from those students – the sample work – how they responded to … the layout of the work, the solution and everything, they were already talking about that some of them were better than the others. I thought that was really good and obviously by the time I gave them the key processes and refine that … put that into perspective so now OK I am going to focus on how they represented it and they made a statement with regards to things like that. So I thought that was really good. I thought a lot of them really contributed to it compared to probably all the video sessions that we have had. I thought a lot of them got more into it. I was quite happy with that

Q2. In terms of the professional development, this last lesson. I want you to describe the aspects of the PD that you used most in the planning of and doing that lesson?

[redacted] Sorry, say that again.

Steve: What aspects of the PD did you use most in planning and doing that lesson? This is the last PD session and the materials.

[redacted] I don't understand, what aspect of … you mean…

Steve: If you think in terms of the professional development and the materials that come with it, what aspects of that have you used most in the planning and doing of this lesson?

[redacted] Are you talking about the problem-solving aspect?

Steve: In general, what did you use most in planning and doing the lesson? What you took from that PD if you like?

[redacted] What I took from that PD? Ok, well basically I have seen most of my students become more involved in with regards to the way they think about problems. Unlike before they would just get going without thinking much. I would say most of them are thinking about the problem before they actually write things down. For me that is an achievement in a way in the sense that they are actually doing the thinking before actually putting anything down. From that aspect I think we have made a …

Steve: In terms of actually using materials, you have followed pretty much the lesson plan?

[redacted] Yes, that is what I have done, yeah.

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Figure 4.4: Post lesson 4 interview with Imran, transcript.

Q3. Could you just briefly describe this lesson is different compared to how you teach normally?

[redacted]OK, quite different. I would say that this is probably a better lesson in the sense that you are asking the students to think most of time and discuss most of the time in pairs which is most likely to generate a lot of positive results than the normal … the most of the time we are doing SOHCAHTOA and I give them the formula and they just use it and apply it straightaway. However, in this case I see them talking more about the problem and actually make it constructive criticism of things and applying their prior knowledge. I think that is really good because the one thing we were talking about, I wasn't thinking that they were good at thinking on that line. I think that was good.

Steve: I am going to talk about these last few questions and talk about the professional development we have done all the session we have done and all the materials we have looked at. Perhaps also think about your experience of doing now four lessons. You might have done other things as well.

Q4. So as a result of taking part in the PD, what do you think has changed as a result of taking part in the PD? I am not just talking about in these lessons I am talking about overall.

[redacted]I have come to understand that really these problem-solving skills are so crucial to teachers learning that is what I have come to realise that and I have been doing that to my classes now. I tend to withhold more and let them think than give and they just get on with it because I do that now most of the time because I see that holding back a little bit sometimes and getting them to think then when they struggle I help them. I help them more that way than the way I would normally do it … just give them what they need to solve the problem with and they get on with it. I see that this generates more thinking from their end and doing that it makes their maths a lot better. To be quite honest with you quite a number of them in this classroom are becoming a lot stronger in their maths then I am quite pleased. The girl over there,[redacted] if you saw here last year, year ten, you would think she was not a set one kid, she is improved so much she has got A*s in her grades now so I am quite happy that she is able to think well about things. Since we have started the PD I have sorted like been doing that most of the time with them.

Steve: So giving them more chance to think and discuss the problem rather than stepping in? Ok and you have done that to some degree in other classes.

[redacted]Yeah in fact I have been carrying that with my other top sets which I see in the next lesson.

Steve: Is that something you find difficult to do?

[redacted]I always find that difficult.

Steve: Why?

[redacted]Its probably the case of not being confident enough to exploit … to see … to hold an answer. Because I used to teach in London and I just teach in South London and most

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Figure 4.5: Post lesson 4 interview with Imran, transcript.

of the kids in my school were quite weak from deprived home and you were teaching and they just don't get it and you had to give them so I got used to that. And I think it is a good experience that … you start to see that well actually not all kids are like that some of them can actually think through the problem just be patient enough. I think since we started doing this I have been a bit more patient not rushing to give, holding back and letting them think. I have been doing that quite a bit, not just with my top-set, with my bottom sets as well.

Steve: But you still find it difficult

[redacted]I still find it difficult. At least I am a lot better than the way it used to be before.

Steve: I just want you to think about the whole PD and everything that you have done. I just want you to think about anything that you have particularly seen in the video are there any of the materials that have stood out that you think have been paritculalry important or particularly useful to you as part of this.

[redacted]Well what I saw in the videos and the handouts and all that is obviously a well-planned lesson taking into consideration the kind of kids you have got in the classroom. That is the reason that sometimes when I look at these problems I tend to just adapt to my class I won't particularly go with exactly what is in the lesson plan I would sort of like adapt it to my lesson. So I have seen a lot of well-planned lessons in there and there is a very good relationship in the way the teachers relate to the kids …

Steve: So in the videos?

[redacted]Yeah in the videos. I thought that was excellent as well.

Steve: As examples of how possibly it could work in your classes?

[redacted] Yes, how possibley it could work in my class and also confidence, sort of like having high expectations of the kids as well.

Steve: So seeing those models?

[redacted]Yes, seeing those models. I think that is really good and the other thing also that I would … the confidence that they have in going ahead with this. To be honest with you if anything what actually made me want to go through this was just to build my confidence a bit

Steve: Have there been examples of where you have thought, I just couldn't do that.

[redacted]Many

Steve: Having this structure and this lesson plan where you can just step through it and …

[redacted]I will give you an example some of my sets, like my current set two. I am finding it difficult to teach them similarity in 3Ds. Because I am thinking they are not taking it in. They are struggling with the one in 2D. Sometimes I speak to[redacted]"How would you teach this, how would you do that?" Those kinds of things and this is one of them, being able to do that is really a breakthrough that you are able to, not just to keep spoon-feeding – if I

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Figure 4.6: Post lesson 4 interview with Imran, transcript.

can use that word – but holding back, let them think and I can actually see them getting better.

Steve: So if I was to summarise how I would understand what you are saying. First of all, we haven't really talked about this – the fact that you have taken part in the video-study means that you have had to do it -- So one thing apart from saying "I am just not doing it anymore." You have had to go and engage in doing this, that's been quite an important part of it hasn't it? The other thing is what you have been saying is very important to you is learning how to stand back a bit and learning how to let the students think.

[redacted]Yes. Discussion. Groupwork. It's not something I usually do. I will be honest with you I am enjoying it now. I am still at the very early stage but I think I will do more …

Steve: I was going to ask you that. What stage do you think you are at and where do you think you going?

[redacted]I think I am at the very, very early stage. But I think it would definitely get better, the more groupwork one does and the more you are able to find that [ ] to think and that helps your planning as well.

Steve: In terms of how I understand the PD, there is one aspect that I am going to raise that we haven't talked about. But you have got these video examples, there useful in a sense that you can see people doing it confidently. So you can think about how that might work with your class then also you have got printed materials which you have got a step-by-step way of doing it. That, as I understand, is how you have found the PD important. What about working together as a department? When you come together for these PD sessions, how do you think that has been helpful of not helpful?

[redacted]It has been really helpful to be honest. In the department, I ask a lot of questions anyway. Coming at it as a department … I tend to ask a lot of questions because I know that the more questions I ask, the more confidence the children have in the teacher. So, form that aspect I think … coming at it as a department … I think I have gained more from the interaction in regard to the PD than anything. Does that answer that question?

Steve: Yes it does, and I think that has answered everything that I wanted to ask for the time being. Obviously we have got one last observation to do, whether we can get that done before Easter, I would like to but we have got another PD session to have first then one last observation and then I would like to ask you a few questions again.

4

Figure 4.7: Post lesson 4 interview with Imran, transcript.

Analysis

The first stage of analysis involved constructing a pen portrait for each of the three teachers, summarising the preceding PD session, analysing the lesson and finally extracting aspects of the interview relating to how they used the PD which revealed their motivations and perspectives.

The preceding PD sessions, in each of the three school, had been summarised activity-by-activity and selectively transcribed. I made comparisons between the PD and each of the *into-the-classroom* lessons.

The main part of the analysis involved lesson 2, the *into-the-classroom* lesson, the interview after lesson 4, and any comments made by the teacher in the lesson 2 post lesson interview. The process involved identifying adaptations and palpable features of the lesson and then using the interview responses to identify teachers' explanations about their implementation strategies. The coding for this was done by hand for each of the three teachers, using transcripts of the lesson 4 interviews. The results of this analysis are presented in Chapter 6 (Section 6.2, p. 140).

4.3.6 Study 5: Quantitative analysis of changes in teachers' practices and self-efficacy

I investigated the research questions: *how do teachers' practices change?* And, *how do teachers' self-efficacy beliefs change over the course of the PD?* using a quasi-experimental methodology. I considered how all the teachers, who participated in at least three out of the four PD sessions, believed their teaching had changed over the course of the PD programme. I also looked at how teachers' self-efficacy had changed over the duration of the PD.

The former was based on teachers' self-reports about their practices. I used an instrument developed by Swan (2006a) based on ideas developed by Askew, Brown, Rhodes, Johnson, and Wiliam (1997) (see Table 4.5). Each item was categorised by Swan (2006a, p. 198) as student-centred or teacher-centred in a similar categorisation used by Cuban (1993). Teachers were asked to rate the frequency of use of each approach on a scale of: *almost never*, *occasionally*, *about half the time*, *most of the time* and *almost always*.

I used two instruments to measure teacher self-efficacy. I used a 12-item teacher self-efficacy instrument (see Table 4.6, 87) which was developed by Tschannen-Moran and Woolfolk Hoy (2001) and which had been given extensive validation which I discussed in Section 3.2.3 (p. 43). Tschannen-Moran and Woolfolk Hoy (2001) identified three factors: *efficacy for student engagement*, *efficacy for instructional strategies*, and *efficacy for classroom management*.

I also developed a 20-item instrument that was specific to the ideas presented in the PD and included items that reflected the approaches sug-

Table 4.5: Teachers' self-reported practices instrument items

Item No.	Teacher- or Student-centred	Item
1	T	Students work through exercises.
2	T	Students work on their own, consulting a neighbour from time to time.
3	T	Students use only the methods I teach them.
4	T	Students start with easy questions and work up to harder questions.
5	S	Students choose which questions they tackle.
6	S	I encourage learners to work more slowly.
7	S	Students compare different methods for doing questions.
8	T	I teach each topic from the beginning assuming they know nothing.
9	T	I teach the whole class at once.
10	T	I try to cover everything in a topic.
11	S	I draw links between topics and move back and forth between topics.
12	S	Students work collaboratively in small groups.
13	T	I avoid students making mistakes by explaining things carefully first.
14	T	I tend to follow the textbook closely.
15	S	Students discuss their ideas.
16	S	Students work collaboratively in pairs.
17	S	Students invent their own methods.
18	S	Students work on substantial tasks that can be worked on at different levels.
19	T	I tell learners which questions to tackle.
20	T	I encourage students to work more quickly.
21	T	I go through one method for doing each question.
22	S	I find out which parts students already understand and don't teach those parts.
23	S	I teach each student differently according to individual needs.
24	S	I cover only the important ideas in a topic.
25	T	I teach each topic separately.
26	T	I know exactly what maths the lesson will contain.
27	S	I encourage students to discuss mistakes they make.
28	S	I jump between topics as the need arises.

Possible responses: *Almost never*, *Occasionally*, *About half the time*, *Most of the time*, and *Almost always*.

Table 4.6: Standard teaching efficacy questionnaire (short form) (Tschannen-Moran and Woolfolk Hoy, 2001)

Item No.	Item	Factor
1	Controlling disruptive behaviour in the classroom.	*Classroom management*
2	Motivating students who show low interest in school work.	*Student engagement*
3	Getting students to believe they can do well in school work.	*Student engagement*
4	Helping your students value learning.	*Student engagement*
5	Crafting good questions for your students.	*Instructional strategies*
6	Getting children to follow classroom rules.	*Classroom management*
7	Calming a student who is disruptive or noisy.	*Classroom management*
8	Establishing a classroom management system with each class.	*Classroom management*
9	Using a variety of assessment strategies.	*Instructional strategies*
10	Providing an alternative explanation or example when students are confused.	*Instructional strategies*
11	Assisting families in helping their children do well at school.	*Student engagement*
12	Implementing alternative strategies in your classroom.	*Instructional strategies*

Teachers were asked to rate how certain they can do the above items on a scale of 1–9: 1—*Cannot do at all*, 3—*Can do a little*, 5—*Moderately can do*, 7—*Can do quite a lot* and 9—*Certain can do*.

gested in the PD. This is shown in Table 4.7. I developed this instrument using the approach suggested by Bandura (2006).

Table 4.7: Teaching problem-solving efficacy questionnaire

Item No.	Item
1	Setting out the problem so that students can start working without detailed guidance about procedures.
2	Getting students to reflect individually on the problem and consider their options for strategy.
3	Allowing students to choose what resources to use (PCs, calculators, protractors, compasses and other tools and materials).
4	Helping students organise themselves into effective groups.
5	Facilitating student groups discussing the problem together.
6	Getting students to build on and challenge one another's ideas constructively.
7	Keeping talk mathematical rather than just idle chatter.
8	Ensuring all members of a group contribute.
9	Giving guidance where groups are not working well together.
10	Getting students to behave responsibly and appropriately when working on open-ended problems together.
11	Getting students to use mathematical skills effectively to solve problems.
12	Providing appropriate levels of assistance to struggling students.
13	Crafting good questions that support students' problem-solving.
14	Allowing students to choose what maths to use.
15	Developing mathematical skills and knowledge in this kind of lesson.
16	Encouraging students to present their findings to the rest of the class.
17	Getting students to evaluate their progress on solutions and identify next steps.
18	Providing formative assessment of students' problem solving.
19	Using ICT (e.g. PCs) to support students' problem solving.
20	Ensuring a definite conclusion to the lesson rather than just "stop there and pack up".

Teachers were asked to rate how certain they can do the above items on a scale of 1–9: 1—*Cannot do at all*, 3—*Can do a little*, 5—*Moderately can do*, 7—*Can do quite a lot* and 9—*Certain can do*.

I administered an online questionnaire (using the Bristol Online Survey service `https://www.survey.bris.ac.uk/`), which included all three instruments, before and after the PD programme. I encouraged all teachers in each of the three mathematics departments to complete the questionnaire. I also asked heads of departments to encourage all to complete the questionnaire: 29 teachers completed the questionnaire at the beginning of the project, and 22 teachers completed the questionnaire at the end of the project.

For the analysis I used responses from teachers who had completed both questionnaires and attended at least three of the four PD sessions, the sample was therefore $n = 18$, and the composition of this sample is shown in Table 4.8 (p. 89): 17 teachers attended all four sessions and 1 teacher attended 3 sessions. This included 8 teachers from Boxton, 4 teachers from Barrington and 6 teachers from Norman Fletcher. This was 80%, 57%, and 55%, respectively, of all the teachers in each department who attended at least three of the PD sessions.

4.3.6.1 Hypotheses

Teachers' practices My hypotheses in relation to teachers' practices was that teachers would report less use of teacher-centred approaches (T). The null hypothesis was:

$$H_0 : \mu_{post} - \mu_{pre} = 0 \tag{4.3.1}$$

Table 4.8: Teacher sample in quantitative analysis

Teacher	School
Deborah Imran Lynne Cheryl	Barrington
Amy Tony Mary Christine David Nigel Jane Adrian	Boxton
Matt Cath Jenny Lydia Pete Anne	Norman Fletcher

And the alternative hypothesis:

$$H_a : \mu_{post(T)} - \mu_{pre(T)} < 0 \tag{4.3.2}$$

With a significance level of: $\alpha = 0.05$. The null hypothesis was rejected at $p \leq 0.05$.

Teachers' self-efficacy Teacher self-efficacy consists of three factors: *efficacy for student engagement*, *efficacy for instructional strategies*, and *efficacy for classroom management*. My hypothesis was that the PD would impact on teachers' self-efficacy in respect to *instructional strategies* (TSEis) and *student engagement* (TSEse). I expected that teachers would develop instructional strategies and student engagement but not classroom management. The PD was designed to support the development of the teaching of problem solving, it seemed likely that teachers would become more confident in using student-centred problem solving approaches and would therefore be more efficacious in student engagement. The link I assume here is between student-centred approaches and student engagement.

Since the PD also models a range of pedagogic approaches, I also assumed a link between this and efficacy in instructional practices. Because the PD was promoting a more student-centred approach, it would not have a positive effect on teachers' efficacy for classroom management. I considered that it may even have a negative effect since the suggested approaches are more challenging to manage in the classroom.

My hypothesis in relation to teacher self-efficacy (SE) was:

$$H_0 : \mu_{post} - \mu_{pre} = 0$$

And the alternative hypothesis:

$$H_a : \mu_{post(TSEis)} - \mu_{pre(TSEis)} > 0$$

$$H_a : \mu_{post(TSEse)} - \mu_{pre(TSEse)} > 0$$

With a significance level of: $\alpha = 0.05$. The null hypothesis was rejected at $p \leq 0.05$.

Teaching problem-solving self-efficacy My hypothesis in relation to teacher Problem-solving teaching self-efficacy (PSTSE) was:

$$H_0 : \mu_{post} - \mu_{pre} = 0$$

And the alternative hypothesis:

$$H_a : \mu_{post(PSTSE)} - \mu_{pre(PSTSE)} > 0$$

With a significance level of: $\alpha = 0.05$. The null hypothesis was rejected at $p \leq 0.05$.

4.3.6.2 Analysis

Teachers' practices The data collected using the practices instruments were ordinal variables—categorical data that is ordered (Field, 2009, pp. 8–9). The possible responses were: *almost never*, *occasionally*, *about half the time*, *most of the time*, and *almost always*. I was not certain that these responses would be equivalent to a continuous interval scale. As a result, I used a non-parametric test. Furthermore, this was a within-groups design i.e. I was using a repeated-measures design with the same sample, so I used a *Wilcoxon signed-rank test for matched pairs*. This test involves finding the difference in responses for each respondent and then ranking the differences. The ranks are then 'signed' to reflect whether there has been an increase or decrease. The sum of each of the positive and negative ranks is found to find a test statistic, T. A decision is then made whether to accept or reject the null hypothesis (Field, 2009, pp. 552–553).

The assumptions for this test are:

1. The differences between the pairs must be able to be ranked;
2. A random selection should be used in order to generalise;
3. The difference scores should come from a symmetric population distribution (Nolan and Heinzen, 2008, p. 633).

If the distribution of differences was not symmetrical, I used a *sign test*. This uses the signs of the each ranking and then a binomial distribution to determine a probability. This has less power than the *Wilcoxon signed-rank test for matched pairs* but offers greater freedom (Howell, 2002, pp. 217–218).

I was not concerned with random selection, since I was not going to generalise the results of this quantitative analysis.

I used the same procedures as Swan (2006a). I coded the responses *almost never*—1, *occasionally*—2, *about half the time*—3, *most of the time*—4 and *almost always*—5. I reverse-coded responses to the student-centred items. The responses were summed to give a score for each respondent in the pre- and post instrument ranging from 28–140 (see Swan, 2006a, p. 200). The difference between pre and post scores for each respondent was calculated. I inspected the differences (see Figure 4.8) and concluded the distribution to be symmetrical and therefore it was appropriate to use the *Wilcoxon signed-rank test for matched pairs*.

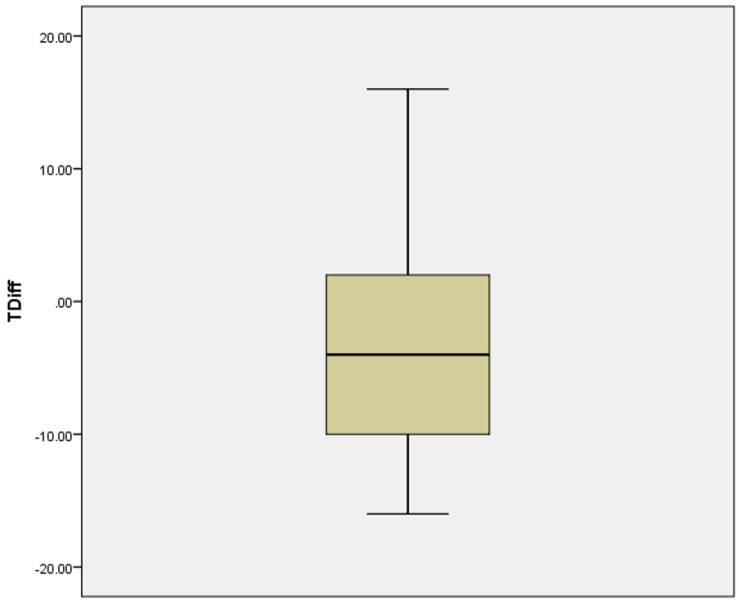


Figure 4.8: Boxplots of differences in pre- and post teacher-centred practices scores.

In order to determine effect size I used a power calculation proposed by Field (2009, p. 558).

$$\frac{z}{\sqrt{\text{Number of observations}}} \tag{4.3.3}$$

Where z can be found by converting the T statistic (see Field, 2009, pp. 553–554, for details)

I used Cohen's convention that a small effect size is approximately 0.2, medium is around 0.5 and large, 0.8 (Nolan and Heinzen, 2008, p. 547).

Where *effect size* is a "standardized value that indicates the size of a difference with respect to a measure of spread, but is not affected by sample size" (p. 543).

Teachers' self-efficacy In both self-efficacy instruments, I assumed the 1–9 Likert scale could be reasonably considered to be a continuous interval variable. As a result I used a parametric test. Since this was a within-groups design, I planned to use a dependant t-test or paired-samples t-test.

The assumptions of the dependent t-test are that:

1. The sampling distribution is normally distributed. In the dependent t-test this means the differences between scores should be normal;

2. Data are measured at the interval level (Field, 2009, p. 326).

There is an assumption of homogeneity of variance and that the scores are independent when using an independent t-test but these assumptions do not apply to a dependent t-test (Field, 2009, p. 326).

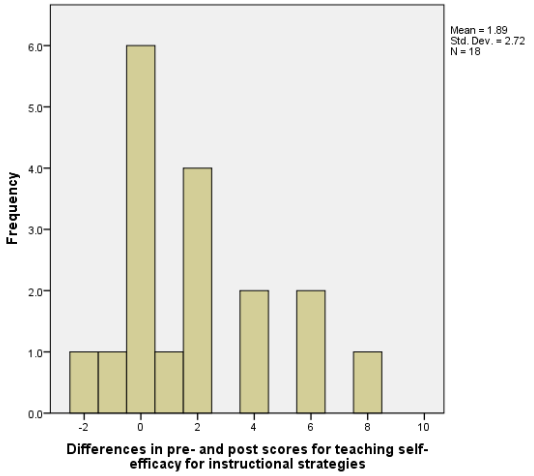
I summed the scores for each of the three factors from the pre- and post questionnaire. (the items and related factors are shown in Table 4.6, p 87). The factors were: *efficacy for instructional strategies*, *efficacy for classroom management* and *efficacy for student engagement*. I also summed the scores for the pre- and post *teaching problem solving efficacy* instrument (see Table 4.7, p. 88). I assumed the responses formed a scale: I present a reliability analysis shortly.

I found the differences in between pre- and post scores for each participant and then analysed these distributions for normality. A visual inspection (see Figure 4.9, p. 93 and Figure 4.10, p. 94) revealed that the distribution of differences for *efficacy for classroom management* (Figure 4.9b) and *efficacy for teaching problem solving* (Figure 4.10) could be considered to be normal. In order to investigate normality further I used a Kolmogorov-Smirnov test. The results of this analysis are shown in Table 4.9 (p. 92).

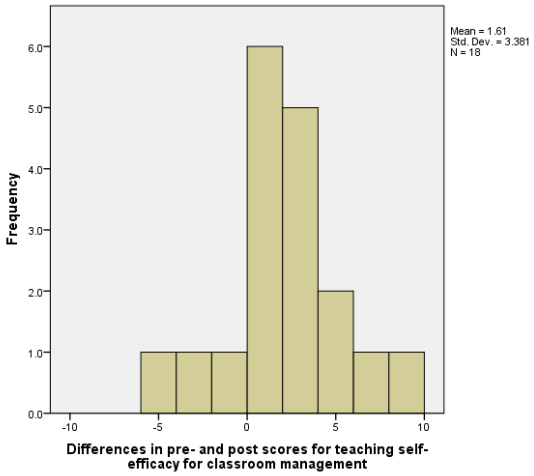
Table 4.9: Teaching self-efficacy: analysis of normality of the difference distributions using Kolmogorov-Smirnov (K–S) test.

Self-efficacy factor	K–S test (D)	*df*	Sig.
Instructional strategies	.206	18	.042*
Classroom management	.150	18	.200
Student engagement	.230	18	.013*
Teaching problem solving	.087	18	.200

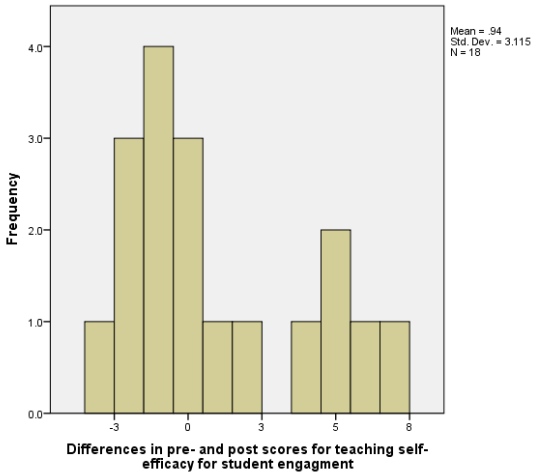
* $p < .05$ therefore significantly **not** normal.



(a) Instructional strategies.



(b) Classroom management.



(c) Student engagement.

Figure 4.9: Distribution of differences between pre- and post scores for teaching self-efficacy factors.

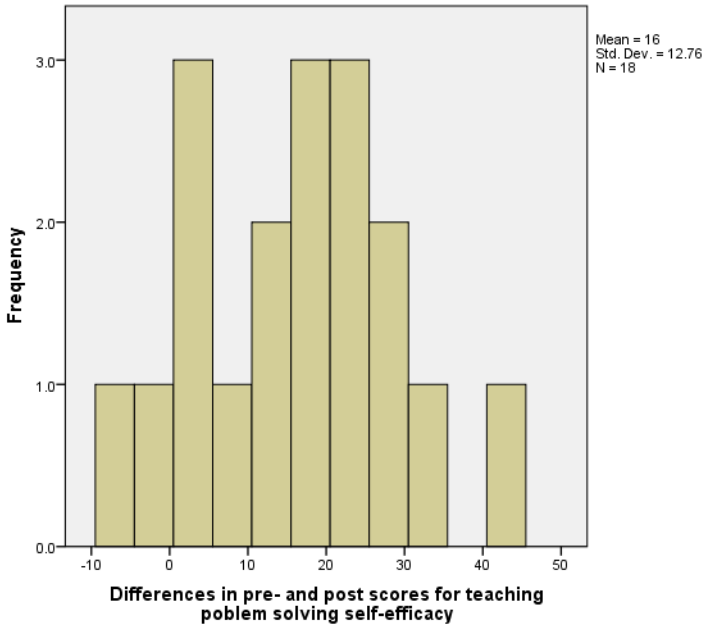


Figure 4.10: Distribution of differences between pre- and post score for self-efficacy for teaching problem solving.

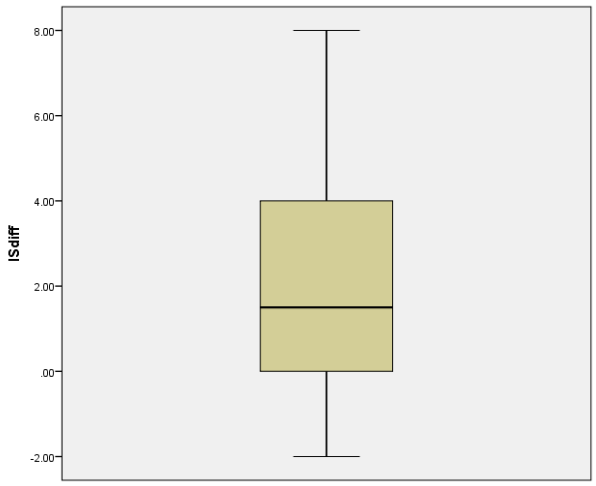
This strongly suggested the differences distributions for *efficacy for classroom management* and for *teaching problem solving* were normal and could be analysed using a dependent t-test. The results of this analysis are presented in Chapter 7. For the *efficacy for student engagement* and for *instructional strategies* I was guided by Leech, Onwuegbuzie, and Daniel (2007) and decided to use a non-parametric test. I begin by testing the assumptions for the *Wilcoxon signed-rank test for matched pairs*.

I inspected the symmetry of the distributions of the differences (see Figure 4.11, p. 95) and I assumed the distribution of the differences in *efficacy for instructional strategies* (Figure 4.11a) to be symmetrical and therefore used the *Wilcoxon signed-rank test for matched pairs*. The *efficacy for student engagement* was not symmetrical so I opted to use the *sign test* which provides and alternative when the assumptions for the Wilcoxon test are not met (Field, 2009, pp. 552–553).

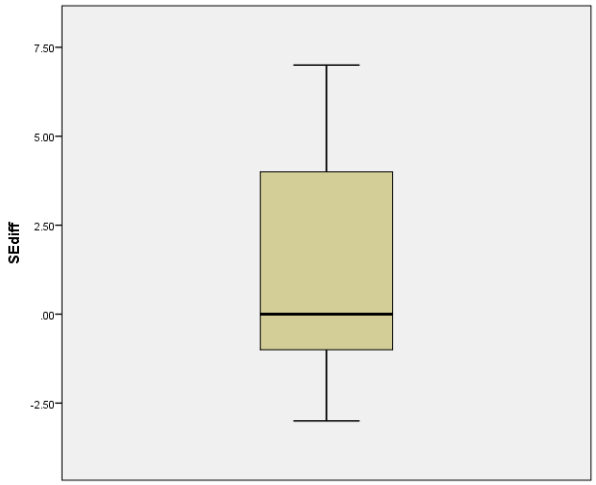
Effect sizes were calculated using the following equation (Field, 2009, p. 332):

$$r = \sqrt{\frac{t^2}{t^2 + df}}$$

I used Cohen's convention that a small effect size is approximately 0.2, medium is around 0.5 and large, 0.8 (Nolan and Heinzen, 2008, p. 547). Where *effect size* is a "standardized value that indicates the size of a difference with respect to a measure of spread, but is not affected by sample size" (p. 543).



(a) Efficacy for instructional strategies.



(b) Efficacy for student engagement.

Figure 4.11: Boxplots of differences between pre- and post teaching efficacy factors.

A note on the validity and reliability of the instruments used

Teacher practices questionnaire In terms of the validity of this instrument, I considered whether it reasonably measured what it claimed to do. In this case, does the instrument gather data that reflects teachers' perspectives on their teaching? I relied on the development work by Swan (2006a) who validated the instrument through comparisons with other data sources. From this he judged the instrument to be valid. I also drew on further validation completed by Pampaka, Williams, Hutcheson, Wake, Black, Davis, and Hernandez-Martinez (2012). They concluded the instrument had reasonable construct validity. While I have concerns that the instrument has not been validated through observational processes, I was happy, in the context of this research, that it would give some indication of changes in teachers' practices.

In terms of the instruments internal validity, Swan (2006a) carried out an analysis of reliability with further education teachers ($n = 120$) and found Cronbach's $\alpha = 0.85$ (p. 200). I carried out a reliability test using pre-test results ($n = 19$) and found Cronbach's $\alpha = 0.91$. Pampaka et al. (2012) carried out a Räsch analysis and found that it was reasonable to assume these items were consistent. I therefore assumed it reasonable to sum the scores for each item and reverse-code student-centred items.

Teacher self-efficacy I discussed the extensive validation that this instrument has been subject to in Section 3.2.3 (p. 43). I therefore concluded that this instrument was valid and reliable for the purposes of this study.

Problem solving teaching self-efficacy This was a new instrument that I had developed and its validity had not been tested. However, I used an approach based on guidance by Bandura (2006). I suggest that results based on this instrument should be treated tentatively. I used pre-test data to conduct a reliability analysis ($n = 18$) and found Cronbach's $\alpha = 0.89$. I decided that it was reasonable to accept the items in this instrument as forming a scale and I assumed it to be valid. Although further testing would be required to confirm this.

4.3.7 Study 6: Qualitative analysis of changes in teachers' perspectives and practices

There were two aspects to this study. The first involved the analysis of teachers' interviews to consider changes in teachers' perspectives, self-efficacy and practices. The second analysis involved looking at how teachers' practices changed through the programme using observational data.

Interviews

For the qualitative analysis of how teachers' perspectives and practices changed over the course of the PD programme, I used data from teacher interviews, these were the same interviews I used in the analysis of how teachers used the PD materials (Section 4.3.5.2. p. 80). I also used data from interviews with heads of departments, these interviews took place after the PD sessions. The methodological approach I used for this aspect of the research was *grounded theory* (Corbin and Strauss, 2008).

Grounded theory generally starts without theory (Corbin and Strauss, 2008, p. 40); however, there are exceptions where, for example, "... a previously developed framework is closely aligned to what is being discovered in the researcher's present study" (p. 40) or "... to develop middle-range theory, a previously identified theoretical framework can provide insight, direction, and a useful list of initial concepts" (p. 41). In this analysis, I used *social learning theory* as a starting theory, this was also guided my decision to use the analytic case study approach as proposed by Yin (2009).

From *social learning theory*, I derived some initial concepts to guide coding and analysis. These were *confidence*, *motivation* and *self-efficacy*. I also considered how teachers' beliefs changed as an alternate or potentially complementary explanation. I therefore used concepts such as *beliefs*, *perspectives* and *orientations* in relation to teaching and learning.

Grounded theory is underpinned by *theoretical sampling*. This approach is characterized by Corbin and Strauss (2008), as follows:

> Analysis begins after the first day of data gathering. Data collection leads to analysis. Analysis leads to concepts. Concepts generate questions. Questions lead to more data collection so that the researcher might learn more about those concepts. This circular process continues until the research reaches the point of **saturation** [original emphasis]; that is, the point in the research when all the concepts are well defined and explained. (Corbin and Strauss, 2008, pp. 145–146).

In Section 4.3.5.2 (p. 80), I described the interview strategy used as a *sequential protocol development* approach. This was consistent with *theoretical sampling*. While the selection of schools used a *convenience* sampling approach, different components of the research used different approaches to sampling appropriate to the research question being addressed. In this aspect of the research, looking at teachers' self-efficacy beliefs and how perspectives and self-reported practices changed, I used a theoretical sampling approach. This involved the ongoing analysis of data through the collection process and refining concepts and ideas through the process.

After the first PD module and the third round of teacher interviews, I carried out a thematic analysis and developed an interview protocol guided by the initial codes described above. The protocol is shown in Figure 4.12. In addition, through the sequence of interviews, I also used a theoretical

sampling strategy at a more informal level, the data from each round of interview were analysed and I wrote analytic summaries; these guided the focus of questioning in successive interviews and in my observations of each department, as a whole.

1. How did you find that lesson?
2. Describe the aspects of the PD that you used most in planning and doing that lesson.
    a. Why were they/was that more important than other things that you saw in the PD?
    b. Why did you think that was particularly important?
    c. Describe some of the aspects of the PD that you have seen that you have incorporated directly into this lesson.
3. Describe the way in which this lesson is different to the way you teach normally.
4. As a result of taking part in the PD what do you think has changed in the way you generally teach?
5. What are the most important aspects or features of the PD?
6. What are the challenges in teaching in the ways suggested in the PD?
7. In what ways, if any, has your views about mathematics or teaching mathematics changed as part being involved in the PD?
8. Have you noticed any changes in the way students approach problem-solving?

Figure 4.12: Post-lesson interview protocol used in the fourth round of teacher interviews.

Eight case study teachers (see Table 4.10) were interviewed. In the fourth-round interview, I asked teachers to, '*describe the way in which this lesson is different to the way you normally teach*'. This was to elicit the extent to which they believed the approach suggested in the PD was different to how they normally taught. I then asked a more direct question about changes in teaching, '*as a result of taking part in the PD what do you think has changed in the way you generally teach*'.

In order to encourage teachers to talk about the difficulties they faced in teaching using the suggested approach, I asked, '*what are the challenges in teaching in the ways suggested in the PD?*' I used this question to explore how confident and motivated teachers were in the suggested approach.

Teachers were asked, '*in what ways, if any, have your views about mathematics or teaching mathematics changed as a result of taking part in the PD?*' With this question, I was asking, more directly, about teachers' beliefs and perspectives.

A similar approach was used in the analysis of interviews after the PD sessions. After the second interview, which took place after the first PD module follow-up session, I analysed the data using the approach described above and developed an interview protocol (see Figure 4.13).

The teacher interviews were audio-recorded and partially transcribed, the interviews with heads of departments were fully transcribed. I coded the data using the following categories: *beliefs*; *confidence and motivation* and *practices, pedagogy and teaching*. I also considered whether data in these categories related to changes in self-efficacy, beliefs or practices. I

Table 4.10: Case study teachers interviewed.

Teacher	School
Barry Imran	Barrington
David Adrian Christine	Boxton
Cath John Pete	N. Fletcher

1. How do you think that went?
2. Who do you think did the planned lesson?
    a. What do you think the barriers were to doing the lesson?
3. What was the most important messages and ideas of this PD module?
4. What do you think teachers have taken from the this PD module?
5. What do you think was the biggest challenge for teachers who did the lesson planned in the PD?
6. Describe what aspects of the PD the teachers found most useful (eg. Video or printed material, tasks or lesson plans).
7. Describe the teachers who find it more and less difficult to do these kinds of lessons.

Figure 4.13: Post-PD interview protocol.

used the fifth round of interview for respondent validation, although I did not directly present findings, I attempted to assess the clarity of the concepts developed through the analysis of the data thus far.

I completed the coding for teacher interviews by hand, identifying aspects of the interview which related to particular categories. For the PD interviews I carried out the coding using software (NVivo). An example of the coding and nodes is shown in Figure 4.14 (p. 101). This shows the coding process from one category, teacher confidence. Each section represents a post PD session interview at each school, then each reference is part of the interview that referred to teachers' confidence and how the PD impacted on teachers' confidence. A similar coding was carried out for teachers' practices and teachers' beliefs about teaching and learning. I combined the results of the analysis of teacher interviews and post-PD interviews in order to provide data triangulation. In other words, using data from different sources in order to arrive at conclusions, in this case I used teacher interview data and data from post PD interviews with heads of departments. I was also able to consider what I had observed in lessons and PD sessions in arriving at my findings. This was further subject to methodological triangulation, by looking at the results of this analysis in comparison with the quantitative study.

Lesson observations

In this part of the study, I carried out an analysis of the observed lessons from the three case study teachers I considered in Study 4 (Section 4.3.5, p. 77). I observed these three teachers—Imran, David and Cath—at five points through the project.

The first observation took place at around the same time, just before the first PD session (in the results I refer to this in lesson 1). The second observation took place after the first PD session; this was the introductory session of the first PD module. Teachers planned this lesson based on the ideas presented in the PD. The third lesson (lesson 3) took before the second PD module. Lesson 4 followed the introductory session of the second PD module and was based on the ideas suggested in the PD session. There was a final observation. In all lessons, except lessons 2 and 4, teachers were asked to teach a problem-solving lesson. In lessons 2 and 4, the lessons were based on the problem-solving approach suggested in the PD.

The aim of this part of the study was to identify how teachers' practices might have developed in teaching problem solving over the course of the PD. By using the same teachers as I did in Study 4, I was able to triangulate the analysis of the observation data with the analysis of interviews with those same teachers.

Principally, this analysis is concerned with observation. I used the lesson analysis approach that I described in Study 4 (Section 4.3.5, p. 77). I am not going to repeat the details here but summarise the key points.

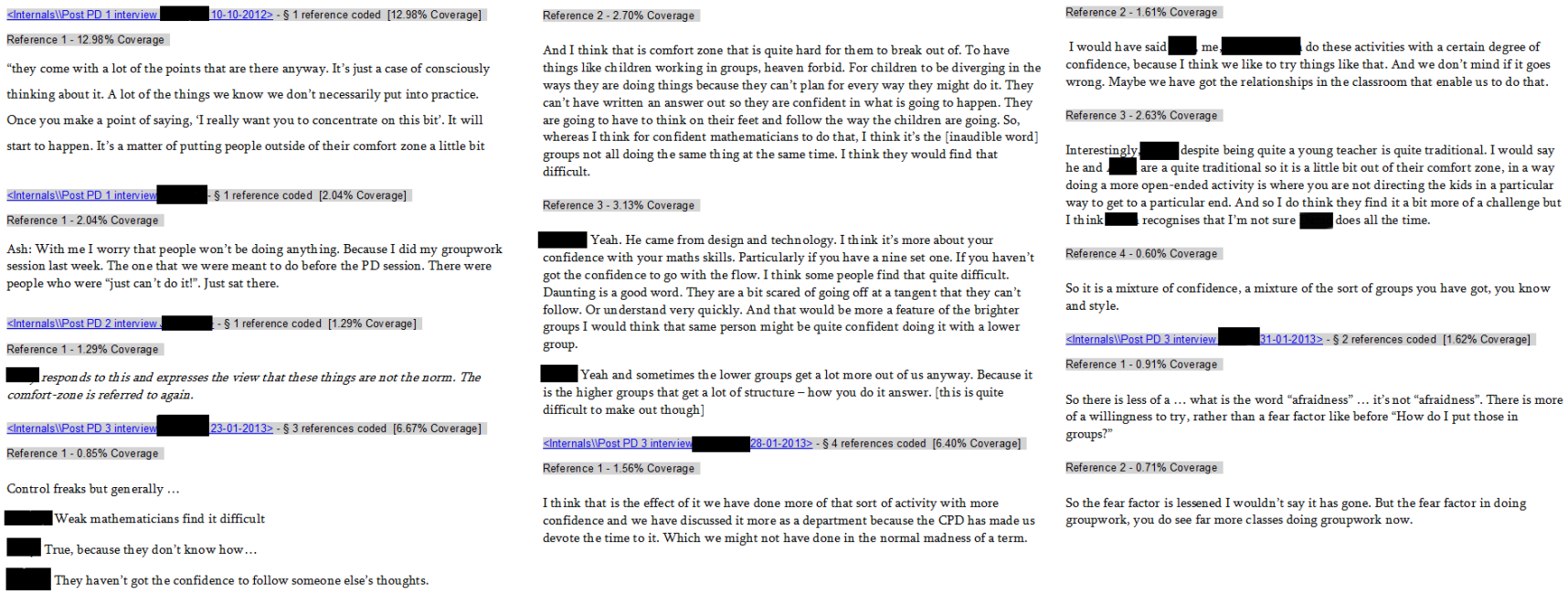


Figure 4.14: Example of coding for the category of *teacher confidence* from the post-PD interviews, using NVivo.

The analysis is based on coding lesson 'episodes'. They are '... periods of time during which the class is engaged in one relatively coherent type of classroom activity" (Schoenfeld, 2013, p. 5). The *episode* types I identified were:

- **Whole-class** *episodes* – the characteristic of this type of episode was that the teacher led the events and might include, for example, whole-class discussion. This type of episode was further classified as:
  - *Launch* – the teacher introducing a problem, task or activity.
  - *Teacher exposition* – a lecturing or explaining type of whole-class episode.
  - *Teacher directions* – the teacher is giving instructions about classroom organization or the way in which some activity should be undertaken.
- **Small group work** – students work in groups of two or more on a task or activity.
- **Student presentations** – students present their work to the whole class.
- **Individual work** – students working on their own on a problem.

A colour coding scheme was devised for this classification and is shown in Figure 4.15. As with other studies (Beeby et al., 1979; Clarke et al., 2006; Schoenfeld, 2013) the identification of episodes was found to be reasonably reliable without having to undergo more formal tests of inter-rater reliability.

Episode code	Description	Colour	
N	Not coded		
W	Whole class		Whole class: teacher led
W(L)	Launch		
W(E)	Exposition		
W(D)	Directions		
G	Small Group Work		
P	Student presentations		
I	Individual work		

Figure 4.15: Lesson structure: the coding used for the different types of episode in a lesson.

The results I present in Chapter 7 (Section 7.2, p. 170) are an analysis of how the patterns of episodes changed over the five observed lessons. This means that I was looking at the way in which the teacher provided time for

students to work collaboratively on problems and how this featured in the lesson. This analysis is intended to complement and triangulate results of the other studies.

In the final part of this chapter I discuss ethics, before I provide an overview and summary to conclude the chapter.

4.4 Ethical considerations

The project was carried out in accordance with the British Educational Research Association's (BERA) *Revised ethical guidelines* (2004). Data was stored and used in accordance with the relevant sections covered by the Data Protection Act (1998). Details of the research were submitted to and approved by the University of Nottingham School of Education Ethics Committee.

The headteacher or principal of each school was asked for written permission to collect data. All potential participants were asked to give their written consent to participating in the research. It would not have been possible to have informed consent from the parents or guardians of all the children before filming lessons. In order to overcome this, the schools' existing consent was used. It was explained to schools they would need the prior or existing parental consent for video or photographs to be taken of students. In cases where parents specifically refused consent, students were asked to work in other classes for that lesson, although this only affected two classes in one of the schools where parental consent had not been given for two students.

It was agreed that video recordings would not be used for any purpose other than to help with data analysis unless we had the teachers' prior consent. Ethical information was given to individual participants on consent forms and also provided in the project information booklet.

4.5 Summary

In this chapter, I have described the methods and methodological approach using a range of observational, interview and survey methods using case study methodology and addressing the following research questions.

1. How do teachers use the professional development materials: what do they attend to and why?
2. How do teachers' self-efficacy beliefs and practices evolve?
3. Which practices do teachers find easiest or most difficult to adopt?

The research was composed of six related studies using different methods and units of analysis:

Study 1 Contextual factors (Research question 1)

Study 2 How mathematics departments implemented the professional development materials (Research question 1)

Study 3 Teachers' observations in professional development sessions (Research question 1)

Study 4 How teachers implemented the ides in the professional development in lessons (Research question 1 & 3)

Study 5 Quantitative analysis of changes in teachers' self-efficacy beliefs and self-reported practices (Research question 1)

Study 6 Qualitative analysis of changes in teachers' self-efficacy beliefs and self-reported practices (Research question 2 & 3)

I present the results in the following three chapters. Chapter 5 presents the results of Study 1 and 2, chapter 6 presents the results of Study 3 and 4 and Chapter 7, the results of Study 5 and 6. In Chapter 8, I interpret these results in respect to *social learning theory*.

Chapter 5

The schools and the departments and how they used the PD

In this chapter, I present the results of the analysis of the school's context and the character and culture of each of the mathematics departments. The results presented in this chapter address the question, 'how do teachers use the PD materials?' at the level of the department.

I begin with an analysis of the external context and, in particular, the schools' accountability contexts. This provides a summary of the schools' examination results and inspection findings.

Following this I present an interpretive account of each department, its character: the department culture and leadership style and an assessment of the extent to which the PD was integrated into school-level development plans.

I then present an analysis of how departments used the PD, by looking at the extent to which each department implemented the PD sessions consistently with the PD aims. This is an analysis of the *fidelity* with which the PD was implemented.

Finally, I further reduce the data and present a summary and synthesis of how the PD cohered at different contextual levels: the *external context*, *school-level* and *department-level*. I also summarise the longitudinal *fidelity profiles* for each school.

I use the term *coherence* to represent the extent to which the PD aligns with contextual factors at the different levels. I also refer to coherence characteristics, these are the contextual characteristics at the different levels that relate to the coherence of the PD. For example, if the school has a high coherence characteristic then the PD is closely aligned to the school strategy and aims. As such I am considering the reciprocity of coherence and context, and identifying the coherence characteristics of the department, school and wider culture.

5.1 Accountability context

In this section, I present the results of my analysis of *coherence* in relation to the schools' accountability context. The notion of *coherence* in relation to PD I considered first in Chapter 2 (Section 2.2, p. 8) in the analysis of research in relation to effective PD. This I developed further in Chapter 3 (Section 3.3, p. 57) where I related *coherence* to the effects of context and communities and to *social learning theory*. I described the approach to this aspect of the study in Chapter 4 (Section 4.3.1, p. 67).

I begin with each school's examination results and the judgements they received from their most recent OfSTED inspections. The results for each school, since 2009, are summarized in Table 5.1 and illustrated in Figure 5.1.

Boxton was the highest performing school; the number of students achieving five A* to C grade GCSEs, including English and mathematics, was well above the national average and increasing year-on-year. Norman Fletcher performed similarly to Boxton in the past, although results fell in 2011–12. Hilltown had improved year-on-year since 2009, with results rising above the national average in 2011–12. Barrington's results were below national average and had been static since 2009. It was noticeable that students in mathematics in Hilltown and Boxton were making progress above the national average, while at Norman Fletcher progress was below the national average (see Table 5.1). While Barrington and Norman Fletcher's results were below the national average, Hilltown was marginally above that threshold. Boxton's results were comfortably above the national average.

Table 5.1: School examination data.

	Percentage of pupils making expected progress in maths (2012)	Percentage of pupils achieving five or more GCSEs (or equivalent), at grades A* to C, inc. English and maths			
		2009	2010	2011	2012
Barrington	46	39	43	45	39
Boxton	77	61	69	70	77
Hilltown	61	32	53	58	61
N. Fletcher	53	60	69	68	53
England	**68**	**50.7**	**55.2**	**58.2**	**58.8**

Note: Data from DfE (2013).

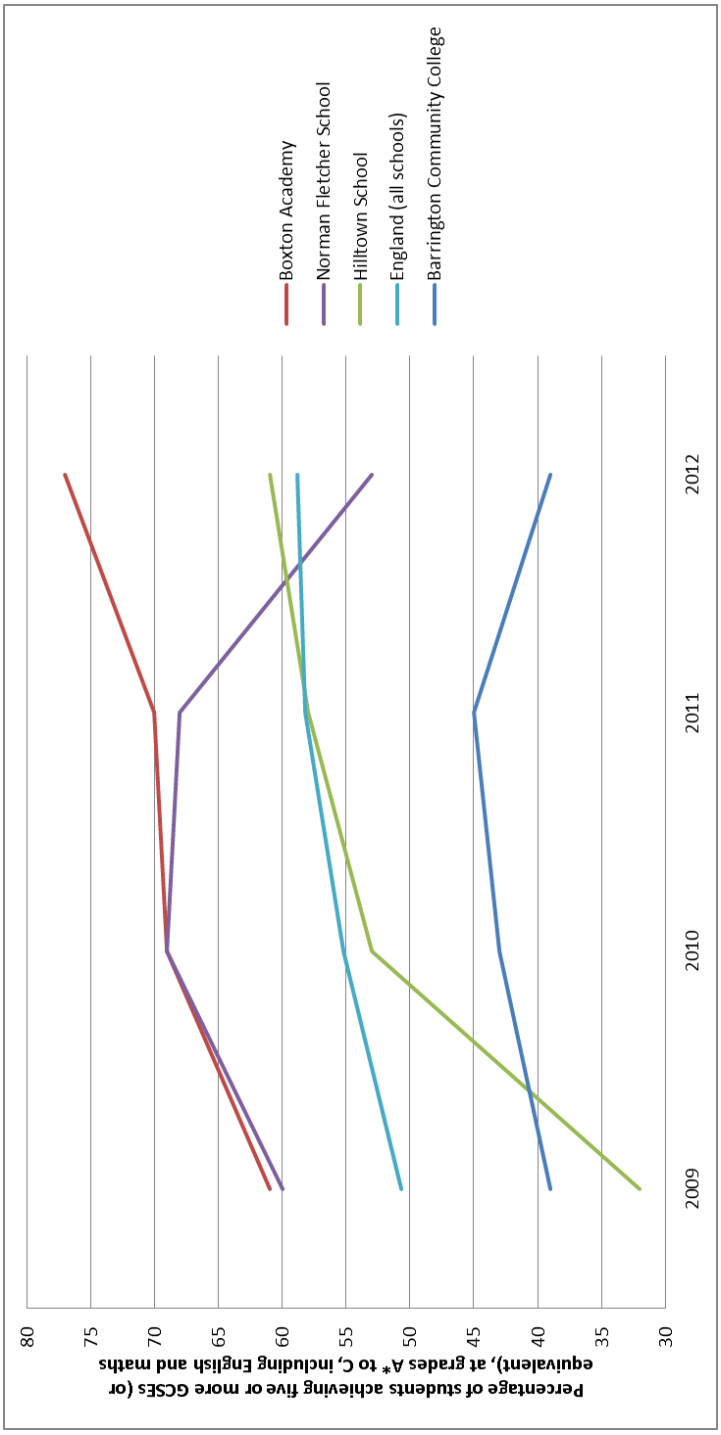


Figure 5.1: Examination performance of each of the four schools, 2009 to 2012.

Table 5.2: School inspection data.

School	Date of last inspection	Overall effectiveness
Barrington	September 2009	Grade 2 *Good*
Boxton	May 2012	Grade 1 *Outstanding*
Hilltown	September 2012	Grade 3 *Requires improvement*
N. Fletcher	December 2011	Grade 1 *Outstanding*

Note: Most recent overall judgement of effectiveness by Office for Standards in Education (OfSTED) inspection teams.

The schools' inspection data are presented in Table 5.2. Boxton and Norman Fletcher were described as 'outstanding' schools. This had implications for the frequency of inspections. Schools that were judged to be 'good' or 'outstanding' would normally be inspected every five years (OfSTED, 2013). However, if there was some cause for concern, like for instance a sudden decrease in results, this may prompt an inspection. This was a concern at Norman Fletcher, where results fell below the national average in 2011–12 (see Table 5.1 and Figure 5.1).

Barrington received a 'good' judgement in 2009. However, results remained below the national average since then. The head of department was concerned about this and was expecting an inspection while this research was being carried out. There was also concern that this would result in a 'requires improvement' grade, prompting more frequent inspections by OfSTED. A school that receives a 'requires improvement' grade is monitored by OfSTED and receives a further inspection within two years (OfSTED, 2013). Just after this research was completed the school was graded 'inadequate' and placed in special measures.

Overall Boxton was achieving good results and was highly regarded by OfSTED. Norman Fletcher had good results but had suffered a recent setback, but had been well-regarded by OfSTED in its previous inspection. Barrington was struggling to achieve results comparable with the national average but had been judged to be a 'good' school by OfSTED. Finally, Hilltown had improving results but had been judged to be requiring improvement by OfSTED.

I characterized each school as *high coherence*, *moderate coherence* and *low coherence* (see Table 5.3). I considered the schools' examination results and OfSTED judgements. I used examination results and OfSTED judgements as principal characteristics of school and department context, since these drove the strategy and aims of each of the schools, as was consistent with the observations made by Perryman et al. (2011). I summarised it to be a 'high' contextual coherence when the school's results were good and there was a positive trend. I gave a *moderate* summary if the schools results were about the national average and the OfSTED judgement in the

most recent report was 'good'. I gave 'low' to contexts that were more demanding than this. The rationale and procedure for this was described in the previous chapter (Section 4.3.3, p. 73).

School	Contextual coherence
Boxton	High
Norman Fletcher	Moderate
Barrington	Moderate/Low
Hilltown	Low

Table 5.3: *Coherence* analysis based on accountability contexts.

5.2 The mathematics departments

In this section, I build on my initial analysis of *coherence* in the four schools, with an analysis of initial meetings and interviews with heads of departments. I develop this analysis of *coherence* by considering the perspectives of heads of departments and the culture of the departments and schools.

From my initial meetings with heads of departments I constructed a descriptive account of each department. I also considered the potential for *collective participation* and *leadership* in the PD. This combined with my analysis of context provided me with initial perspective on how the PD might cohere in each school and mathematics department. I continue to examine these initial assumptions through the next two chapters, where I present a micro-level analysis which looks more closely at the mathematics teachers' use of the materials and how their skills changed as a result of participation.

5.2.1 Barrington Community College

I was introduced to the school by long-serving head of department, Deborah. She had been at the school for almost thirty years. In our first meeting, at the start of the project, the school's examination results were prominent in our discussion. She was reasonably pleased with the results in mathematics—56% of students achieved an A* to C at GCSE—this was just below the national average of 58%. Deborah believed that an OfSTED inspection was imminent, because of this, she had considered withdrawing from the project.

Barrington had a history of investigative and student-centred approaches in mathematics. The previous head of department was an active member of the ATM and well known in the mathematics education community; while at Barrington she had promoted an investigative and problem-solving culture. I was interested if this had left a legacy of this kind of teaching.

However, following her departure and through the 1990s and 2000s, the general approach in the department was more traditional and teacher-centred. Deborah joined the department during the investigative teaching phase. She had enjoyed teaching in that way and was keen to reintroduce more student-centred problem-solving in the department. Although supportive of teaching through investigation and problem-solving, she welcomed the structure that was introduced as a result of the National Curriculum after 1988.

There were seven mathematics teachers in the department (see Table 5.4, p. 111); in addition there were a teaching assistant and cover supervisor who were permanently attached to the mathematics department.

Deborah described a 'central core' in the department as her, Cheryl, Lynne and Barry. The four of them, she explained, were keen to try out different approaches and to share and develop resources. She also explained that during the previous summer term they had done some collaborative planning and observed each other teach.

Of the other teachers, Deborah explained that Imran was quite traditional in the way he taught and felt less confident about using a more student-centred approach. However, she explained that he expressed a willingness to try new things. Danny, the youngest member of the department, was the most traditional teacher and seemed unwilling to try other approaches. Brian was extremely experienced and was approaching the end of his career. He was also susceptible to ill-health and would be off work for quite long spells. Brian tended to teach the lower ability students—his approach was generally traditional teacher-centred. The way in which Deborah described and characterized her department was unique amongst the heads of departments; she appeared to have good understanding of individual motivations and personalities.

Barrington has a particularly good reputation for A level mathematics; it achieved good results and received attention from local schools that were keen to learn from them. Deborah felt that a lot of their success post-sixteen was as a result of their approach to teaching in years 10 and 11; where, she believed, interest and capacities for mathematics were fostered. My observation of the department confirmed this had some basis. Although, it was likely that the type of teaching she referred was an aspiration of the core group of teachers.

Deborah explained the challenges of being a 14–18 school: as soon as students started in year 10, having come from one of the feeder schools, there had to be a focus on preparing them for examinations. In an 11–16 or an 11–18 school, she said, you have longer to get know the students before examinations.

The school's motivation for participating in the project was department led. The school leadership gave their agreement and were aware of the project. However, it was not integrated into a school-level strategy. This suggested a lack of coherence at school level. At department level, Deborah

Table 5.4: Mathematics teachers, Barrington Community College.

Name	Rôle	Age range	Number of years in current school	Number of years teaching	Level of mathematics qualification	Teaching qualification
Deborah	Head of department	51–55	24	29	Degree level with 50% or mathematics	PGCE
Lynne	Assistant head of department	36–40	10	12	Degree level with 50% or mathematics	PGCE
Brian	Main scale teacher	56–60	5	35	Degree level with 50% or mathematics	Cert. Ed.
Cheryl	Main scale teacher	31–35	3	4	Degree level with 50% or mathematics	PGCE
Imran	Main scale teacher	36–40	4	8	Postgraduate	PGCE
Danny[1]	Main scale teacher					
Barry	Main scale teacher	41–45	2	9	Degree level with 50% or mathematics	PGCE

Note: Teachers who took part in the embedded video case study are in bold font.
This is a record of teachers who were working in the department at the start of the study.
[1] Did not complete questionnaire.

explained that they had been particularly interested in teaching problem solving, but spoke in terms of her core group.

5.2.2 Boxton Academy

It was a second career for Tony, the head of department, he had previously worked in industry and in a supervisory rôle. He had been a teacher for ten years and had worked a Boxton throughout that time. He was promoted to acting head of mathematics in the previous year to replace the retiring long-standing head of mathematics, Joyce. Joyce continued to have a rôle in the department, teaching further mathematics, but mainly worked with other schools in a consultancy and advisory rôle. She had a desk in the mathematics office and was around to support and mentor Tony.

Tony was very enthusiastic about his rôle, working with staff and students. He was very keen to become involved in this research project; he explained how he believed it would support some of the things they were trying to do as a department and as a school. The work with the University of Nottingham featured on an A3 summary of the school and department improvement plan displayed on the mathematics office wall. This visible and overt level of strategic integration was unique to Boxton.

It was notable how, during PD sessions, the team would attempt to reach consensus, whether it be over the way they would do a particular lesson they were trying out, or as a collective response to an issue in the department. The previous head of department, Joyce, explained to me that she had always attempted to promote a team spirit and make it the heart of the department's ethos. Information about the teachers is included in Table 5.5 (p. 113). Amy, a young teacher in the department, had been given responsibility for the PD project as part of her curriculum responsibility in the department. She organised and led all the PD sessions.

Over thirty years this school has grown to be a leading school in the area. This has not been an overnight success but a lengthy and sustained developmental effort. I got the impression that at the heart of this success were the things I observed in the maths department: the collegiality and the willingness to work as a department to learn and develop. There were, however, external factors that have helped this to happen, like for example, the changes and restructuring of other schools in the area and continuity has been an important factor: since the school opened in the 1950s it has had just three headteachers.

5.2.3 Hilltown School

I included this school even though the mathematics department did not complete the PD programme. The reason for this is that it illustrated the pressures that a school experiences as a result of an OfSTED inspection and the effects of accountability.

Table 5.5: Mathematics teachers, Boxton Academy.

Name	Rôle	Age range	Number of years in current school	Number of years teaching	Level of mathematics qualification	Teaching qualification
Amy	Assistant head of department	<25	2	3	Degree level with 50% or mathematics	PGCE
Nigel	Head/ assistant head of year	26–30	5	5	Degree level with 50% or mathematics	PGCE
Adrian	Main scale teacher	<25	1	32	Degree level with 50% or mathematics	PGCE
Mary	Main scale teacher	<25	4	4	Degree level with 50% or mathematics	PGCE
Jane	Head/ assistant head of year	31–35	4	4	Potgraduate	PGCE
David	Assistant head of department	31–35	8	8	Degree level with 50% or mathematics	PGCE
Tony	Head of department	41–45	9	10	Degree level with 50% or mathematics	Not stated
Christine	Main scale teacher	31–35	12	12	Degree level with 50% or mathematics	PGCE
Ted[1]	Main scale teacher	46–50				
Phil[1]	Main scale teacher (NQT)		1	1		
Joyce[1]	Previous HoD					

Note: Teachers who took part in the embedded video case study are in bold font.
This is a record of teachers who were working in the department at the start of the study.
[1] Did not complete questionnaire.

At the beginning of the project I interviewed Graham, the newly appointed head of department at Hilltown. He was excited and energetic about being involved in this project. Although in his fifties he was relatively new to the profession. The development of the teaching of problem solving was something that he was personally very interested in. He had the support of the new headteacher who gave permission for the department's involvement. Graham had enlisted the help of Sally to be responsible for the PD project. Sally organised and led the PD sessions; she was in the second year of teaching.

Early in the project the school was inspected by OfSTED and was judged as requiring improvement. This meant that the school would be monitored subsequently each term. At the end of the first term of the project Graham resigned as head of mathematics but continued part-time as a main scale teacher. Both Graham and Sally left Hilltown altogether at the end of the academic year.

In this school, the effect of inspection had profound effect on the culture of the school. I observed how it created a great deal of pressure on staff to improve examination results rapidly and also to demonstrate teaching styles that the school's leadership perceived OfSTED to value. In an interview with a member of the mathematics teaching staff at the end of the projected, he expressed the view that these pressures and repeated observation had been, in his opinion, the reason why Sally had resigned. He told me that in repeated observations her teaching had been judged inadequate.

I believed the perceived pressures also contributed to Graham's departure. He was coy about the reasons, he suggested that he wanted to concentrate on his charitable work. To my mind, the 'requires improvement' judgement and the schools zealous efforts to improve on this was a factor. He had, after all, been very enthusiastic about the project at the outset.

I interviewed an assistant head teacher at the end of the project and he explained that although the PD was valuable, it was necessary that they focussed on improving their OfSTED grading. He explained while ideas in the PD were important, they had to be more focussed on teaching and learning. This I interpreted to mean implementing teaching approaches and lesson structures that the school leadership considered OfSTED would value.

5.2.4 Norman Fletcher School

This was a large school. Information about teachers is included in Table 5.6 (p. 116). Anne, the head of department, had been at the school for almost twenty years. She described the challenges of running a large mathematics department of fifteen teachers as "like steering a super-tanker". Norman Fletcher, as an 'outstanding' school, had been successful. However, I did see some of the most challenging student behaviour of all the schools in the lessons I observed. One teacher explained to me that because of the

size of the school you could never get to know all the students—there were some students that go through the school who the teacher never knew. As a result, it was difficult to establish and maintain relationships with students.

The school's governing body came into dispute with one of the main teaching unions over the school's plans to become an academy in 2011, becoming an academy means that the school is funded directly by the DfE and outside of Local Authority control. There were several days of industrial action. This was resolved, but there continued to be evidence of mistrust between the teaching staff and the headteacher. The headteacher was on long-term sick-leave during the academic year, 2012–2013. OfSTED, in 2011, described the headteacher and the leadership team as exceptional.

Prior to the project I met with Anne, the head of department and Margaret, one of the two assistant heads of department. They explained they were interested in developing the teaching of problem solving in the department. They had a 'push on it' a few years earlier and introduced problem-solving tasks into the scheme of work, they did not feel they were being used effectively. In addition, they explained, the school was interested in developing students' capacity for independent learning; the PD would be consistent with that aim. The need to develop students' independent learning was one of the minor criticisms raised in the OfSTED report of 2011. Other than recognising the need to develop independent learning, there appeared to be little integration of the PD into the school-level strategy.

Anne was less buoyant and upbeat after the summer, GCSE results had been disappointing. The department was subject to an internal 'quality review'. This included lesson observations by members of the school leadership team, and scrutiny of student work and student progress data. This put the department under pressure at the beginning of the year.

I observed a more managerial and hierarchical culture in the mathematics department than I had in the other schools. I believed Anne did not promote a collegiate and collaborative culture and did not appear happy to devolve decision-making. However, I felt—based on my discussions with Anne in interview—it was not necessarily the favoured approach of the head of department, I think she believed that this was the approach she had to take to manage a large department.

Having presented an overview of each department, I look at how each department used the PD materials in the next section. The results presented in this section are summarized using the approach described in the previous chapter (Section 4.3.3, p. 73) and presented in Table 5.7 (p. 117).

In the next section I build on this analysis and consider, more closely, how each of the mathematics department used the PD materials.

Table 5.6: Mathematics teachers, Norman Fletcher School.

Name	Rôle	Age range	Number of years in current school	Number of years teaching	Level of mathematics qualification	Teaching qualification
Anne	Head of department	41–45	17	22	Degree level with 50% or more mathematics	Cert Ed.
Matt	Assistant head of department	26–30	5	5	Degree level with 50% or more mathematics	PGCE
Raul	Main scale teacher	46–50	2	1	Degree level with 50% or more mathematics	GTP, PGCE
Ian	Assistant Headteacher	36–40	2	14	Degree level with 50% or more mathematics	PGCE
Pete	Main scale teacher	41–45	1	18	Degree level with 50% or more mathematics	GTP[1]
John	Main scale teacher	51–55	6	8	Degree level with 50% or more mathematics	PGCE
Margaret	Assistant head of department	51–55	4	16	Degree level with 50% or more mathematics	PGCE
Jenny	Main scale teacher	46–50	8	5	Degree level with 50% or more mathematics	PGCE
Cath	Main scale teacher	41–45	1	1	Degree level with 50% or more mathematics	PGCE
Sidney	Main scale teacher	51–55	26	31	A Level	PGCE
Lydia	Main scale teacher	41–45	7	16	Degree level with 50% or more mathematics	PGCE
James	Main scale teacher	26–30	5	6	Degree level with 50% or more mathematics	PGCE
Bill	Main scale teacher	61–65	5	21	Degree level with 50% or more mathematics	PGCE
Malik	Main scale teacher	26–30	2	3	Degree level with 50% or more mathematics	PGCE

Note: Teachers who took part in the embedded video case study are in bold font.
This is a record of teachers who were working in the department at the start of the study.
[1] Previously a design and technology teacher.

School	PD integration with school aims	Dept. leadership style	Dept. culture
Boxton	moderate	informal & participatory	cooperative & team-spirited
N Fletcher	low	hierarchical & authoritarian	individual & cooperative
Barrington	low	participatory & authoritarian	central group – collaborate/ outer group – individual
Hilltown	low	crisis	high turnover

Table 5.7: Summary of departmental cultures.

5.3 *Fidelity* of the PD sessions

In this section, I present the results of the analysis of the *fidelity* with which the PD was implemented by each of the schools. *Fidelity*, as I use it here, is a measure of the how closely the PD sessions were implemented in relation to the design intentions. It is categorical ordinal scale of 0–3 with 3, meaning high fidelity and 0, no fidelity. I described the details of this measure and the analysis in Section 4.3.2 (p. 68). The results are presented in Table 5.8 (p. 118). The *total weighted fidelity scores* for each PD session is illustrated graphically in Figure 5.2 (p. 119).

An inspection of the graphical presentation of the *total weighted fidelity scores* for each session illustrates how at Boxton and Norman Fletcher *fidelity* to the design intentions of the PD materials fell away over the course of the project (see Figure 5.2, p. 119). At Barrington it remained consistently high. I now consider these results from an analysis of my observations of the PD sessions and interviews with the PD leader after the PD sessions.

At Barrington, Deborah, the head of department, led the PD sessions. She ensured there was a full hour after school for the sessions. I observed that each of the four sessions were unhurried, all the activities were carried out and in a way consistent with the intentions of the PD. Deborah went to some effort to ensure that she interpreted and implemented the PD correctly. She was conscientious in the way she followed the PD materials throughout the project; she contacted me on two occasions through the project to check details. It was evident from the observation of the PD sessions that the instructions given at the beginning of the project had been followed closely. This is reflected in the consistently high *weighted fidelity scores* through the project.

At Boxton, the *fidelity* scores were high for the first two sessions. These

Table 5.8: Fidelity scores for all PD sessions.

Barrington

Module	Questioning and reasoning												Involving pupils in peer and self-assessment											
	Intro session						Follow-up session						Intro session						Follow-up session					
Activity	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
Suggested time (mins)[1]	5	15	20	20	-	60	20	10	15	10	-	55	10	20	20	10	-	60	10	15	15	15	5	60
Fidelity score[2]	3	3	3	3	-	-	2	3	2	3	-	-	3	3	3	2	-	-	2	3	3	3	3	-
Weighted fidelity score[3]	0.25	0.75	1.00	1.00	-	**3.00**[4]	0.73	0.55	0.55	0.55	-	**2.36**[4]	0.50	1.00	1.00	0.33	-	**2.83**[4]	0.33	0.75	0.75	0.75	0.25	**2.83**[4]

Boxton

Module	Fostering and managing collaborative												Involving pupils in peer and self-assessment											
	Intro session						Follow-up session						Intro session						Follow-up session					
Activity	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
Suggested time (mins)[1]	10	10	20	10	10	60	20	10	10	10	-	50	10	20	20	10	-	60	10	15	15	15	5	60
Fidelity score[2]	2	2	3	3	2	-	2	3	2	3	-	-	2	3	1	1	-	-	1	2	1	1	1	-
Weighted fidelity score[3]	0.33	0.33	1.00	0.50	-	**2.50**[4]	1.20	0.40	0.60	0.40	-	**2.60**[4]	0.33	1.00	0.33	0.17	-	**1.83**[4]	0.17	0.50	0.25	0.25	0.08	**1.25**[4]

Norman Fletcher

Module	Questioning and reasoning												Assessing the key processes											
	Intro session						Follow-up session						Intro session						Follow-up session					
Activity	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
Suggested time (mins)[1]	5	15	20	20	-	55	20	10	15	10	-	55	10	20	15	10	-	55	10	15	15	15	5	60
Fidelity score[2]	3	3	3	3	-	-	3	3	0	3	-	-	2	3	3	1	-	-	2	0	0	0	0	-
Weighted fidelity score[3]	0.25	0.75	1.00	1.00	-	**3.00**[4]	1.09	0.55	0.00	0.55	-	**2.18**[4]	0.36	1.09	0.82	0.18	-	**2.45**[4]	0.33	0.00	0.00	0.00	0.00	**0.33**[4]

Notes:
[1] The time suggested in the PD materials to spend on each activity (introductory activities not included).
[2] Estimated fidelity score (how close the activity to aims suggested in the materials), 3–high, 2–moderate, 1–low, 0–not done (see text for more explanation).
[3] Time weighted fidelity score based on suggested activity time and total suggested duration of PD session.
[4] Total weighted fidelity score for each session.

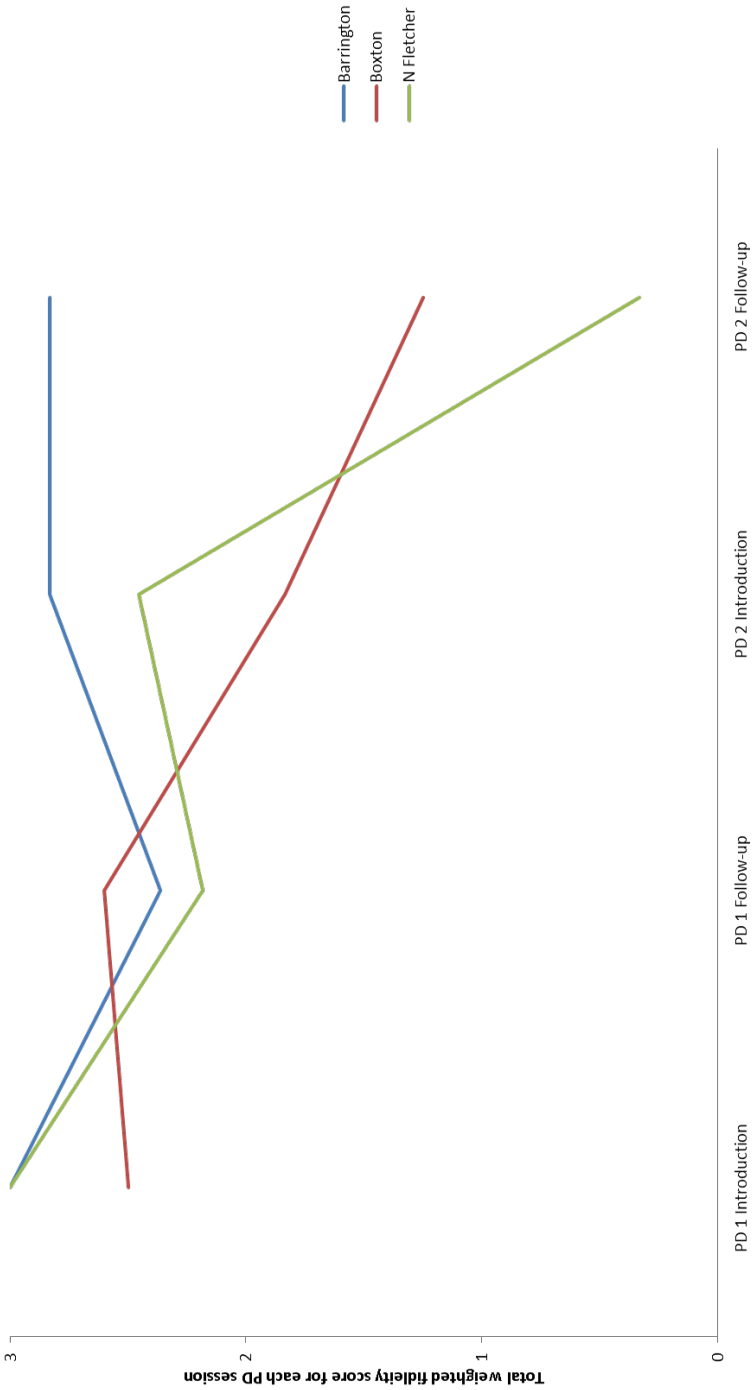


Figure 5.2: Weighted fidelity scores for each PD session, based on Table 5.8, (p. 118).

Table 5.9: Structure and time organization of the *Fostering and Managing Collaborative Work* module, *introductory* session

Activity		Duration
1	Experience a mathematical discussion.	10 mins
2	Reflect on your discussion.	10 mins
3	Observe a discussion lesson.	20 mins
4	Discuss implications for teaching.	10 mins
5	Plan a lesson.	10 mins
	Total	60 mins

were the *introductory* and *follow-up* sessions of the *Fostering and Managing Collaborative Work* module. During the second module, *Involving Pupils in Peer and Self-assessment*, *weighted fidelity* scores fell away. In the *introductory* session the score was 1.83 and in the *follow-up* session it was 1.22 (see Table 5.8). This compares to 2.50 and 2.60 in the sessions in the previous module.

The main factor in the first two sessions at Boxton was time. The head of department had originally wanted after-school sessions. However, the school would not agree to this, there were a number of other planned meetings and the head of the department did not want to impose on members of the department by asking them to volunteer for more after-school meetings. He therefore decided to ask Amy to do the sessions at lunchtime, which were 45 minutes. This immediately had an impact on *fidelity* since she had to make the decision to leave parts of the session out and reduce the amount of time that could be spent on each activity.

To illustrate what she did, I describe the approach she took to reducing the *introductory* session of the *Fostering and Managing Collaborative Work* module. There are five session activities in this module, the suggested times for each activity is shown in Table 5.9. Amy reduced activity 1, 2 and 4 by 5 minutes each and reduced activity 3 by 2 minutes. It was these reductions that gave an overall fidelity score of 2.50 rather than 3. There were similar economies made in the *follow-up* session. I consider this to be a high-fidelity implementation, it was when the fidelity score was less than 1.5 that I was concerned that the PD was not being implemented in a way consistent with that intended.

This is what happened in the second module at Boxton. In the *introductory* session of the *Involving Pupils in Peer and Self-assessment* module the fidelity score fell to 1.83. Time was a major factor in this. There are five activities in the session. There was an introduction that lasted 9 minutes, activity 1 was reduced from 10 to 5 minutes, activity 2 from 20 to 8 minutes, activity 3 from 20 to 6 minutes and activity 4 from 10 minutes to 3 minutes. A number of teachers were late for the lunchtime session. It

is possible the PD can be undertaken effectively in this amount of time. However, I believe this was the point at which there was a threat to integrity and there was a danger that the ideas and messages within the PD started to become lost.

The situation became much worse in the *follow-up* session (weighted fidelity score, 1.25, see 5.8 and Figure 5.2). Time was an issue again, members of the department were late to the lunchtime session and the one-hour session was done in a half hour. More importantly the discussion in the PD was more focussed on accountability issues rather than formative assessment in the teaching of problem solving. In activity 5, Amy led the discussion, but talked about preparation for examinations and then talked about what criteria OfSTED would use to judge the quality of teaching. This activity was intended to be a chance for teachers to plan assessment strategies for the future, but other preoccupations crept in. This was the point at which I concluded that PD was no longer cohering with departmental perspectives.

Norman Fletcher started the first module with a high fidelity score (see Table 5.8, p. 118 and Figure 5.2, p. 119). The head of department had prepared carefully and a full hour was used after school for the PD sessions. She decided to use departmental meeting time for the purpose of the PD. In the follow-up session the *weighted fidelity score* for the session is lower than the introductory session. This is as a result of one 15-minute activity being omitted completely. The missed activity involved watching a video clip of teachers thinking out loud. The idea of the activity was to model and support students in understanding how problem solving is not a 'neat' linear process.

The introductory session of the third PD session at Norman Fletcher showed increased fidelity (*Assessing the key processes*, introductory session), but not as high as the first session. The reason for this was that the session had to be reduced to 50 minutes in order to allow some time for a department meeting. It was not a dramatic fall in the level of fidelity but it is important to point out how the PD sessions were competing for time with other meetings and work that departments felt they had to do. At Norman Fletcher they had used calendared department meeting time for the PD. The head of department explained to me that this was proving to be difficult, as there were issues in relation to preparing classes for examinations that needed to be presented to the department.

At Norman Fletcher there was a dramatic reduction in fidelity between the *introductory* session of the second module and the *follow-up*. In the *follow-up*, Matt, one of the two assistant heads of department, ran the session. None of the materials were used and the session involved teachers discussing their experiences of the *into-the-classroom* lesson. This could, in part be explained by the fact that Matt had not been attendance at the pre-project meeting and so may not have been familiar with the expectations of how the PD sessions should run.

School	PD Fidelity profile
Boxton	declining
N Fletcher	declining
Barrington	stable
Hilltown	ceased participation

Table 5.10: Summary of schools' longitudinal *fidelity* profiles.

In Table 5.10 I summarise the fidelity profiles for each of the schools.

5.4 Summary and synthesis of results

The results presented in this chapter are summarised in Table 5.11 (p. 123). I summarise the external *contextual coherence* from Section 5.1 (p. 106); the *PD integration with school aims*, *department leadership style* and *department culture* from Section 5.2 (p. 109); and the *PD fidelity profile* from the previous section. The approach used and descriptors were described in the previous chapter on methods (see Section 4.3.3, p. 73).

It was Desimone et al. (2002) who proposed the characteristic of PD *coherence*. In their words:

> ...the degree to which the activity promotes **coherence** in teachers' professional development, by incorporating experiences that are consistent with teachers' goals, aligned with state standards and assessments, and encourage continuing professional communication among teachers (p. 83).

My discussion of this in relation to PD effectiveness research was presented in Chapter 2 (Section 2.2, p. 8). However, I developed this from the analysis of further professional development research (Chapter 3, Section 3.3, p. 57). As such the conception of *coherence* became a complex interwoven concept involving *macro-* and *micro-level* contextual influences (Cooney and Krainer, 1996). Krainer (2006) developed this further and proposed a framework of *content*, *communities* and *context*. *Content* refers to the PD, its aims and how it will be carried out. *Communities* refer to those doing the PD and the *context* refers to determinants and influencing factors at school, district and national level.

This goes beyond the initial conception of coherence proposed by Desimone et al. (2002). Therefore, I identified some key aspects or indicators of this complex contextual field. These are shown as the column headings in Table 5.11. These can be further organised into a hierarchical model

School	Contextual coherence[1]	PD integration with school aims[2]	Dept. leadership style[2]	Dept. culture[2]	PD fidelity profile[3]
Boxton	high	moderate	informal & participatory	cooperative & team-spirited	declining
N Fletcher	moderate	low	hierarchical & authoritarian	individual & cooperative	declining
Barrington	moderate/ low	low	participatory & authoritarian	central group – collaborate/ outer group – individual	stable
Hilltown	low	low	crisis	high turnover	ceased participation

[1] Summary of results from Section 5.1: *Accountability Context* (see Table 5.3, p. 109).
[2] From Section 5.2: *The Mathematics Departments*, (see Table 5.7, p. 117).
[3] Summary of results from Section 5.3: *Coherence of the PD Materials: Fidelity of the PD Sessions*, (see Table 5.10, p. 122).

Table 5.11: Summary of contextual results presented in Chapter 5.

Table 5.12: Hierarchical model of PD *coherence*.

Contextual level or field	description	Indicators used in this research
External	Curriculum, assessment, accountability and education policy.	*Contextual coherence* where I considered accountability context.
School-level	The extent to which the school integrates the PD into the school improvement and strategic plan. The level of support in terms of resources. The extent to which the school evaluates the PD.	*PD integration with school aims*, .
Dept.-level	For example, department culture, leadership style and collaborative culture.	*PD leadership style* & *department culture* .

of coherence and contextual factors at in different fields and at different levels. This is shown in Table 5.12.

The final analysis in relation to the results in this chapter was to summarise the data in relation to external, school-level and department-level. contextual factors. This is summarised in the following and presented in Table 5.13 (p. 125).

Boxton

Boxton's context was the most coherent with the aims of the PD. It was achieving good results and OfSTED had recently judged it to be an outstanding school. It therefore had few pressures to improve examination results in comparison with the other schools. It had a ***high coherence*** characteristic in relation to the *external contextual field*. The PD was integrated into the school aims in a moderate way. The PD was integral part of the school and department development plan but the school did not conduct any evaluation of its own. The fidelity with which the PD was implemented declined through the project. In terms of *school-level contextual factors* the coherence was ***moderate***.

The head of department had an informal leadership style and participated with the department; he delegated the leadership of the PD a colleague. The department culture was team-spirited and teachers demonstrated a willingness to work together and collaborate. At ***department level*** the character of the department leadership and the potential for collaboration and collective participation was ***moderate*** (see Table 5.13, p.

Table 5.13: Summary of schools' PD coherence.

School	External contextual factors	School-level context	Dept.-level context	Fidelity profile
Boxton	high	moderate	moderate	declining
N. Fletcher	moderate	low	low	declining
Barrington	moderate/ low	low	moderate	stable
Hilltown	low	low	low	ceased participation

125).

Norman Fletcher

At Norman Fletcher the decline in examination results resulted in the *external context* having ***moderate*** coherence; in spite of the fact that the school had been judged 'outstanding' by OfSTED. Since the PD was not integrated into school aims or evaluated the *school-level* coherence was ***low***. At *department level*, the limited level of collaboration and hierarchical leadership style resulted in ***low*** coherence (see Table 5.13, p. 125).

Barrington

Examination results were below the national average, while the previous inspection had found the school to be 'good'. Coherence in relation to *external contextual factors* was ***moderate/ low***. At *school level* the PD was not integrated into school development plans, the coherence was ***low***. At the level of the department there was skilled leadership but only half of the department were collaborative, so the department-level coherence was ***moderate*** (see Table 5.13, p. 125).

Hilltown

Although results were improving and above the national average, the 'requires improvement' judgement meant the *external contextual* coherence was ***low***. This was a department initiative and so the *school-level* coherence was ***low***. At department-level the high turnover of staff meant the coherence was ***low*** .

Table 5.13 provides and overall summary of the data in this chapter along with a summary of the longitudinal fidelity profile. This summary will be discussed further in Chapter 8 and compared and integrated with the results presented in the next two chapters. In the next chapter I look more closely at how teachers used the materials. Following this, I present

results of how teachers' practices and self-efficacy beliefs changed as a result of participating in the PD.

Chapter 6

How the PD materials were used by teachers

In the previous chapter, I presented the results of my investigation of how departments used the materials, with a particular emphasis on how the PD *cohered* with the schools' contexts and cultures. In this chapter, I take a closer a look at how teachers interacted with the PD materials and how they used the materials in lessons.

I begin by looking at one aspect of a PD session. Through this I explore, in-depth, how teachers engaged with the PD materials. I used observational learning theory as the basis for this analysis. I considered the PD to offer alternative models of practice—as suggested approaches to teaching. I explore, through the analysis of teachers' discussion, what aspects of the PD they attended to. From this, and using observational learning theory, I explain the possible motivations for the aspects of the PD that the teachers attended to and noticed.

Although this aspect of the research draws on a single case, this case provides a level of intensity that allows teachers' considerations, when confronted with new and alternate approaches, to become visible. Then, by using *analytic generalisation* (Yin, 2009), i.e. generalising to theory, I was able to make more general claims about teachers' observational learning in the context of reform-oriented professional development.

Furthermore, this component of the research is embedded into a wider project using analysis at multiple levels. The triangulation strategy draws on a *combined levels of triangulation* approach (Cohen et al., 2011, p. 196) which I introduced at the beginning of the previous chapter.

In the second part this chapter, I present the results of an analysis of how teachers took the ideas in the PD and implemented them in their classrooms. This involved three case studies of teachers—one from each school. While I considered following the teachers who participated in the discussion that I analysed for the first part of this chapter, I wanted to balance the investigation across the three schools. My analysis is of the lesson they did after the first PD session—the *into-the-classroom* lesson where they try out the ideas. My focus was on how they took the ideas

suggested in the PD (the models) and used them in their lesson.

The two parts of this chapter address the research question, *how do teachers use the PD materials: what did they attend to and why?*

6.1 An analysis of teachers' attention in part of a PD session

In this section, I present my analysis of teachers' interaction and discussion in a PD session, in relation to the ideas suggested in the PD.

I explained the methods and how I selected this particular group of teachers, PD session and activity in Chapter 4 (see Section 4.3.4, p. 75). The key aspect of this was that it was based on an *intensity sampling* approach. I selected a case that demonstrated vividly the processes I wanted to analyse. I selected a discussion, in the Boxton mathematics department, between teachers during the *introductory* session of the *Fostering and Managing Collaborative Work* module. This was the first PD module. Similar discussions were observed in other sessions and in other departments. However, this was a concise example that effectively demonstrated features of discussion that revealed *observational learning* processes.

This approach complemented the *analytic generalisation* strategy (Yin, 2009) that I was using; I was generalising this vivid case to observational learning theory as a component of *social learning theory*.

My analysis focussed on the teachers' discussion in *activity 3*, where they had observed a video exemplifying the approach suggested in the PD. I considered the discussion the teachers had about this following the video. This was transcribed and shown in Figure 6.1 (p. 137).

There were 10 teachers at the session, as well as a teaching assistant and a PGCE student. The discussion was between the following teachers: Amy, Nigel, Tony, Jane, Mary, Phil and David. Amy was leading the PD sessions and Tony was the head of department. A summary of all the teachers at Boxton is shown in Table 6.1 (p. 129).

A descriptive summary of Boxton's first PD session is shown in Tables 6.2–6.4 (pp. 130–132). This analysis focuses on *activity 3* which starts nine-and-a-half minutes into the PD session. The descriptive summary I produced, for this activity, is extracted from Table 6.3 (p. 131) and is as follows:

> *Amy introduces the video and reads out the questions that are presented in the materials. They watch the longer extract of Eve's lesson. There are a range of responses from members of the department. Mary says she likes the way the teacher encourages students to think about the problem individually—she says*

Table 6.1: Mathematics teachers, Boxton Academy.

Name	Role	Age range	Number of years in current school	Number of years teaching	Level of mathematics qualification	Teaching qualification
Amy	Assistant head of department	<25	2	3	Degree level with 50% or mathematics	PGCE
Nigel	Head/ assistant head of year	26–30	5	5	Degree level with 50% or mathematics	PGCE
Adrian	Main scale teacher	<25	1	32	Degree level with 50% or mathematics	PGCE
Mary	Main scale teacher	<25	4	4	Degree level with 50% or mathematics	PGCE
Jane	Head/ assistant head of year	31–35	4	4	Potgraduate	PGCE
David	Assistant head of department	31–35	8	8	Degree level with 50% or mathematics	PGCE
Tony	Head of department	41–45	9	10	Degree level with 50% or mathematics	Not stated
Christine	Main scale teacher	31–35	12	12	Degree level with 50% or mathematics	PGCE
Ted[1]	Main scale teacher	46–50				
Phil[1]	Main scale teacher (NQT)		1	1		
Joyce[1]	Previous HoD					

Note: Teachers who took part in the embedded video case study are in bold font.
This is a record of teachers who were working in the department at the start of the study.
[1] Did not complete questionnaire.

Table 6.2: Example of PD observations, Boxton Academy, Autumn term, *Fostering and Managing Collaborative Work*, *Introductory* session, part 1.

Activity	Suggested time	Time taken	Aim of activity	Observation summary
Intro	NA	1′	**The importance of discussion:** To present the aims of the session and explain and clarify the importance of discussion.	Amy introduces the module by presenting a list of the session activities. She does not present or use the PD materials to provide an overview of or give any reference to the importance of discussion in teaching problem-solving.
1	10′	4′	**Experience a mathematical discussion:** Teachers are expected to work on a task and to think about their own discussion when collaboratively problem-solving.	Teachers work in groups on the *How many teachers in the UK?* problem (see handout 1, Figure 2.4, p. 20). Towards the end of the activity, Amy distributes all the session handouts. This activity is completed quickly.
2	10′	4′30″	**Reflect on your discussion:** Teachers are encouraged to analyse their discussion using frameworks provided in the PD.	Amy prompts her colleagues to look at handout 2, *Recognising helpful and unhelpful talk* (see Figure 2.4, p. 20). The whole department get involved in the discussion and talk about the way they discussed the problem. There is consensus that much of what they were doing was 'cumulative' talk, building on each others' ideas.

Table 6.3: Example of PD observations, Boxton Academy, Autumn term, *Fostering and Managing Collaborative Work*, *Introductory* session, part 2.

Activity	Suggested time	Time taken	Aim of the activity	Observation summary
3	20′	18′	**Observe a discussion lesson:** To observe video clips of lessons the feature student discussion and collaboration when working on problem-solving tasks. The prompt questions are: • How does the teacher introduce the problem? • What different approaches are being used by pupils? • How does the teacher help pupils to discuss productively? • Can you characterize the types of talk they are using?	Amy introduces the video and reads out the questions that are presented in the materials. They watch the longer extract of Eve's lesson. There are a range of responses from members of the department. Mary says she likes the way the teacher encourages students to think about the problem individually—she says that when they began the discussion they had some ideas. This appears to be an observation about the lesson structure. Phil comments on the use of resources, he says he liked the use of small whiteboards, so they could change their ideas. Tony says he likes the way the teacher asks the pupils, 'why?' and 'why do you think that?' Nigel notices how Eve gave the students very little direction. Amy observes that in order that students have opportunity to develop their collaborative and discussion skills, the level of mathematics in the tasks has to be relatively low. They watch the last part of Eve's lesson.

Table 6.4: Example of PD observations, Boxton Academy, Autumn term, *Fostering and Managing Collaborative Work*, *Introductory* session, part 3.

Activity	Suggested time	Time taken	Aim of the activity	Observation summary
4	10′	5′30″	**Discuss implications for teaching:** This activity is intended to provide practical support for teachers to support student discussion. The principle underlying the activity is that students need to be taught how to discuss.	They concentrate on handout 3, *Ten ground rules for pupil-pupil discussion* (see Figure 2.5, p. 21). Amy suggests that they think about what rules they want as-a-department. There is still collective interest in finding out how many teachers there are in the UK. As a group, they discuss the usefulness of the ten ground rules. There is discussion about whether agreement should be reached within student collaborative groups. Tony asks if there are any of the rules that they are all agree should be used. They then decide which rules they will use. Amy considers group roles and assigning different roles within student groups. Mary suggests that students come up with rules, and this is discussed.
5	10′	10′	**Plan a lesson using one of the problems:**	Amy refers to handout 1, *Problems for discussion.* She suggests that everyone choose a problem to do with a class and work in twos, threes or fours to plan the lesson. They begin to think about the lesson design as a department, 'shall we get them to think about it on their own first?' Christine is concerned about her low-ability group accessing the task. They discuss group sizes and their experiences, whether they should choose the group or let students do this. Effort is made to steer toward agreement and consensus across the department.
Totals	60′	43′		

> *that when they began the discussion they had some ideas. This appears to be an observation about the lesson structure. Phil comments on the use of resources, he says he liked the use of small whiteboards, so they could change their ideas. Tony says he likes the way the teacher asks the pupils, 'why?' and 'why do you think that?' Nigel notices how Eve gave the students very little direction. Amy observes that in order that students have opportunity to develop their collaborative and discussion skills, the level of mathematics in the tasks has to be relatively low. They watch the last part of Eve's lesson.*

They had been watching the first six minutes of an 11-minute example lesson. This features a teacher, Eve, with a year 9 class working on the '*How Many Teachers in the UK?*' problem. The following is a description of the content.

Description of lesson video content

Eve is seen introducing the lesson as, "different to a normal lesson," one in which the aim will be to, "introduce some discussion." She gives the class the problem '*How Many Teachers are there in the UK?*' She explains the that there is very little information in the problem and that she is not going to give them any more information, except that there are about 60 million people in the UK.

The video then shows students working on their own for a few moments. Eve stops the class and then asks the students to work in pairs. Two boys discuss the problem beginning with an assumption, "there would be one head teacher in every school," and that there would be two or three deputy head teachers. One of the boys then suggests there are about 30 pupils in a class and one teacher per class.

The video cuts to another boy who conjectures that there are about 50,000, he says, "because...it's just a guess...I don't know how many schools there are."

Three girls discuss the problem, they collectively consider what proportion of the population is a child. One of the girls suggests a half. Another girl then conjectures there are between 1 and 3 million teachers, "because there are 10 million kids at least." The first girl goes back to her original question, what proportion of the 60 million is a child?

Another group of three girls are engaged in a similar discussion: the proportion of the population that are children. They discuss the validity of the claim, that it is half; they decide this is reasonable. They use the assumption that there are 30 children in a class and that would mean there would be 1 million teachers. One of the girls says she thinks this estimate is too low. She conjectures, "maybe you should times that by the number of schools." She then decides that 1 million seems quite a lot. Another girl says that you have to think about all the other jobs adults do, probably meaning that there is a limit to how many can be teachers.

The video cuts to the boy who conjectured 50,000. Eve asks him, "what part of your life is in school?" She suggests that they (he and the boy he is working with) put some numbers to it, even if they are "rough numbers". The other boy says that they are at school for 16 years, Eve says, "out of?" and the boy responds, "16" then corrects this to 100. Eve suggests they try and link that to their first answer. Eve moves away and the boys try some calculations.

Eve is shown talking to the whole class. She asks that before they work in groups of four—to share their ideas so far—the class should come up with some rules for productive discussion. She offers an example, "if someone says something that is glib, ask, 'how?', 'why?' or 'prove it!' " She also explains that she wants the class to challenge each other. "If someone says something you disagree with, ask them, 'why?' "

Eve asks the class to work in groups and suggests that if they get stuck they ask one of the other members of the groups to explain it.

In one of the groups, a boy is explaining to the two girls in the group, what he and his partner had been doing. They estimated that there were 30 million children in the UK, he says it could be more or less. The second boy suggests that half the adults are working teachers. The first boy says, "Maybe, yes," because, he explains, there are quite a few adults that are not in teaching.

In another group a boy conjectures that there are more children than adults. The boy next to him says, "How do you know?"

Eve asks two girls in another group about their calculations, "This ratio here, what is this about?" They explain that it is the teacher to pupil ratio, 25 : 1. Eve says it sounds reasonable. She says that she is not convinced that there are 30 million children and asks them to think about it a bit more. The three girls then discuss, at some length, when it is you stop being a child.

Amy stops the video at this point.

Analysis of teacher discussion

I now consider the transcript of the discussion between teachers following this video (see Figure 6.1, p. 137).

Amy, who was leading the PD, made the first comment as she stopped the video of Eve's lesson, "it has become unhelpful now, they are just going off on one" (line 2). She was referring to the girls' discussion about the age at which a child becomes an adult.

Their discussion was prompted by Eve asking the group of three girls to examine their assumption, that *half* the UK population is children i.e. 30 million. In the context of the example lesson the discussion that ensues—identifying when children become adults—is important in making a reasonable estimate about how many teachers there are in the UK. Yet, Amy evaluated this as, "unhelpful" and, "going off on one."

In the context of the lesson it is not 'unhelpful'; the aim was to encourage discussion and develop students' problem-solving skills by exploring and evaluating alternative ideas, assumptions and methods. Exploring alternative approaches is a part of this. Therefore, Amy's evaluation is not based on the context of the example lesson, she is making an evaluation based on other criteria. This is interesting since she was familiar with the PD and the aims of the PD because she planned and led the PD sessions.

She was comparing what she observed in the video to her own subjective conceptual ideal of what should have been happening. She had a mental model of student action and behaviour that she considered to lead to effective learning. Through a process of conception matching, she evaluated what she had observed as not particularly or optimally effective. It is also reasonable to assume that Amy felt this issue was important because she had been moved to make a comment and evaluation.

Nigel responded to Amy's comment, indicating concern that the teacher had not intervened to get the students "back on track" (line 3, Figure 6.1). Since the students were making assumptions to prepare estimates of values which they would then use to calculate an estimate for the number of teachers in the UK, Nigel could have meant that the processes by which they were seeking to make assumptions were too divergent. Or, it could have been a more general observation about the approach in the lesson.

His expectation is that the teacher should be directing them toward more reasonable assumptions. However, he does not suggest a means by which this should be done.

Nigel's analysis is consistent with the process by which Amy evaluated an aspect of what she had observed. Nigel is making a comparison with a mental model of teaching. However, since he does not proffer a solution to the situation, it is unlikely that his model has an image or narrative of a solution. This would also explain why he has commented on this aspect of the video: the absence of a mental model or heuristic that would provide him with some means to manage the divergency of student discussion.

Amy then drew attention to the questions that were included in the PD materials and were specific to this activity of observing and discussing an example lesson. She made a further comment about the class going "off-topic" (line 4). She suggested the questions could come in nicely there. She was probably saying that the teacher could have used questioning in order to help steer students' discussion. With this, she is indicating the materials might have an approach to the perceived problem of being 'off-on-one', off-track or 'off-task'. This is the first indication, in this discussion, that the observed model is being considered by teachers in practical terms: something they can use to guide action in their *into-the-classroom* lessons.

The prompt questions included in the PD materials for this activity were:

- How does Eve introduce the problem?
- What different approaches are being used by her pupils?

- How does she help pupils discuss productively?
- Can you characterize the types of talk being used?

Mary commented that she liked the fact that the teacher gave the class time to think about the problem on their own before discussing it in groups (line 5). This comment could be considered as an expression of Mary's general preferences: 'I like this' or 'don't like that'. However, it is probable that Mary was looking at the video and thinking about how she might organise her lesson in the into-the-classroom phase.

Teachers were expected try out the ideas suggested in the PD in their classroom. Therefore, it likely that they were making evaluations based on the knowledge that they would have to try out the approaches illustrated in the video and described in other parts of the PD. Their assessment is an expectancy evaluation. Furthermore, the main source of criteria, for teachers in their expert field, is their practice-based experience—what they have found to be effective. This lends further support to the assumption that teachers are making evaluations based on practice-based experience of what works.

It is not possible to be certain about this and there may be other reasons why they evaluate the example lesson in the way they did. As I have said, they may be based on more general preferences and proclivities. However, even if there are other factors, assessments will be influenced, in at least part, by a forward-oriented assessment of what they believe will be effective. Therefore this analysis remains reasonably valid.

I assume then, an assessment is being made by teachers, whether aspects of what they observe were something that they believe would be effective in their teaching. This is exemplified by Mary's comments. She was making the judgement that this was something that she could do in a lesson. She was making an expectancy judgement about what she had seen in the video. She was expressing the view that this was a pedagogical model that she could use. That she felt self-efficacious in the model she had observed.

Going back to Nigel and Amy's evaluation at the beginning of the discussion: my analysis above means that their evaluation, of the way in which students were permitted to discuss a variety of ideas and approaches to solving the problem, reflected that they saw this—particularly Nigel—as something they would not feel comfortable doing in their classroom.

Returning to the discussion (see transcript in Figure 6.1, p. 137). Amy added to Mary's comment by suggesting that it would give them, "a point going into the discussion" (line 6). Amy was concerned with finding a solution to what she perceived to be unhelpful and divergent discussion. She was conjecturing that the period of individual working might give the group discussion more focus.

Phil said that he liked the use of the small whiteboards (line 7). This is not a response to one of the activity questions, but another expectancy judgement about a pedagogic move he might use successfully in one of his

	10′30″[1]		*Amy presents the questions*[2]
	11′20″		*Amy plays the activity 3 video and then has difficulty finding the video clip she wanted*
	14′20″		*Amy plays the video clip of Eve's lesson "How many teachers in the UK?"*
1	18′16″	**Amy**	We will just play it through and I will put the questions back up.
2	20′	**Amy**	[speaking over the video] It has become unhelpful now, they are just going off on one [referring to the students' discussion in the video].
3		**Nigel**	She is leaving it isn't she? [referring to the teacher], she has to put them back on track [there are some inaudible comments and laughter from other members of the department]. It's like [name of student]...
4	20′26″	**Amy**	I'll just pop the questions up before they share their thoughts with the class, because they went quite a bit off-topic there, so the questions would come in nicely there. If we have a minute of talking about where the questions fit into the video...
5		**Mary**	I liked that the teacher got them to think about it by themselves before they began the discussion...
6		**Amy**	... so they have got a point to go into the conversation with ...
7		**Phil**	They have got the little whiteboards so they can quickly cross anything out.
8		**Jane**	It went individual, to pair, to group ...
9		**Tony**	I like the bit where she asks 'why?' [inaudible] prove it instead of just coming out with ...
10		**David**	... a guess?
11		**Tony**	Yeah.
12		**Nigel**	She didn't direct them, she gave them very little direction.
13		**Amy**	She wanted them to elaborate a bit more.
14	21′30″	**Nigel**	[looking at one of the questions] What were the different approaches used?
15		**Amy**	Probably just guessed.
16		**Teacher**[3]	... guess, yes
17		**David**	That was amazing.
18		**Mary**	I'm not sure that he did, he just didn't have the confidence to explain it. At first he sounded quite confident and then he said he just guessed.
19		**Nigel**	The two lads were going off on the wrong way weren't they? *There is some discussion about some students' assumptions.*
20		**Amy**	... and they went right off task. *Further discussion about the task, assumptions and possible solutions.*
21	22′45″	**Nigel**	There is no maths in there though.
22		**Amy**	No, it's being able to have a try at it.
23		**Mary**	It is coming up with something sensibly that's the thing isn't it? If you gave that to our year 11, it would [inaudible]...
24		**Amy**	You could start them off with this sort of thing because it easier maths and then once they have got good at discussion...
25		**Mary**	But it is making sure that they have done the bits beforehand, before they start
	23′20″		*There is then some discussion about the types of talk.*
	24′20″		*Amy then plays the last bit of the lesson video.*

Notes:
[1] Timestamp on video recording.
[2] These refer to the prompt questions in activity 3, see Table 4.3 (p. 71).
[3] Teacher's voice not identified.

Figure 6.1: Boxton PD session transcript.

lessons. This is a similar judgement to the one made by Mary in line 5. Phil has observed a pedagogical component that he has judged to have functional value, since it is something that he believed he could use in his teaching.

Jane contributed to Mary's observation about students being given individual thinking time. Additionally, she commented on the lesson structure: "It went individual, pair, share..." (line 8). This is the underlying lesson structure included in all the suggested lesson plans and illustrated in the example lessons in the PD. Jane's observation was indicative of a change in character in the discussion. Amy and Nigel were initially evaluative, at a surface level, about what they had observed, Jane was articulating an analysis of the way the lesson was structured. The discussion became analytic at about this point. Moreover, the observation that Jane made also indicated that she was making a functional evaluation: that she could use this kind of structure.

Tony then highlighted a pedagogical move, the way the teacher, Eve, asked "why?" (line 9). He also offered some analysis of this: "...prove it, instead of just coming out with ..." Although his comment was cut short, Tony observed that instead of steering the discussion, Eve asked students to justify their approach. As with the analysis of the discussion so far, this comment was also an expectancy evaluation. The most likely motivation for this comment was to articulate something, about what was observed, that Tony believed he could use effectively in a lesson. This pedagogical element represented a technique that Tony could implement in a problem solving lesson as a way to steer open-ended discussion.

It was David who cut short Tony's previous comment with a suggestion that the teacher's "why?" question was to encourage something other than a guess (line 10, Figure 6.1). He was saying that the move was to promote a bit more thinking in addition to justification.

Nigel then returned to his initial preoccupation which related to the lack of direction offered by the teacher (see line 3). In line 12, he made a further comment: "She didn't direct them..." With this, it is revealed that this still remained an issue for Nigel. Although the other teachers had commented on and started to analyse other aspects of the lesson, Nigel was still considering the teacher's reluctance to give more direction.

Following Nigel's restatement about the lack of direction, Amy responded to the point raised by Tony in line 9 about the use of the question, "why?" She suggested that the question was probably to get them to, "elaborate a bit more" (line 13). She therefore expressed a recognition that this kind of question was to promote student thinking and reasoning.

Nigel then focussed on the prompt questions: "What were the different approaches used [by the pupils]?" (line 14). Amy responded that it was "probably just a guess" (line 15). Another unidentified teacher agreed (line 16). They expressed some scepticism that there was any kind of reasoning behind the student approaches. Amy expressed scepticism about the quality and productivity of the student reasoning she observed in line 2,

when she said the talk had become "unhelpful". It is likely that Amy saw the difficulties in teaching using the suggested approach was in initiating, maintaining and sustaining productive reasoning.

Mary disagreed with Amy (line 18). She said that the reason she thought one of the students appeared to be simply guessing was that he did not have the confidence to express his thinking. This is an insightful observation as she was acknowledging that students' utterances do not always represent the sophisticated reasoning that takes place unarticulated.

Nigel responded once again about the direction that the students were going in, that discussion was unproductive in terms of seeking a solution: "The two lads were going off on the wrong way weren't they?" (line 19). Amy supported this in line 20.

Amy used a term I frequently heard during the project, whether it was in interviews with teachers or observed in discussions in PD sessions: that term was *off-task*. It was used, as it is here, to mean that students were engaged in activity that was not concerned with finding a solution or getting to an answer to a problem. Such is the ubiquity of this term in English secondary classrooms, I heard one boy, in a year eight class at Norman Fletcher, complaining to the teacher that one of his classmates was *off-task*. The term intertwines valued mathematical activity and classroom behaviour. I discuss this further in Chapter 8.

Nigel raised a concern that there was "no maths in there" (line 21). This probably meant that he thought the discussion between students did not feature the development of mathematical fluency i.e. learning how to apply methods already taught.

Amy's next comment in line 24, demonstrates a deeper understanding of the PD aims. She recognised that the lesson was intended to introduce new practices into the lesson: student discussion around a more open-ended problem. This sort of problem she suggested could be used to "...start them off with this sort of thing" (line 24). Then they could progress with more challenging mathematics, "once they had got good at discussion ..." (line 24). This lesson is a way into a new pedagogical approach and new classroom practices.

In the final line (25) Mary suggested that they would have had to do some of the "bits beforehand, before they start". In this she is suggesting that if the mathematical methods required are too difficult, it would be important that before the lesson they were taught some of the techniques required in order that the find it easier to get to a solution. However, the aim here is to give students the chance to work on problems that are unfamiliar and that may be solved in alternative ways but lead to equally valuable solutions. The teaching of 'methods' in advance or what Mary calls, "bits" reduces the problem solving element of the activity and makes it easier to find a solution.

Mary shows here that she is concerned about students not being able to make progress toward a solution. It reveals a functional assessment about the extent to which she believes she will be successful teaching in

the way demonstrated in the lesson. This indicates that she thinks that some adaptation might be needed. It would be more manageable if students had a route through to a solution.

Looking at the discussion overall. There were six issues that were given attention. Four were related to the lesson and pedagogical approaches:

1. Allowing students time to discuss an open-ended problem
2. The lesson structure.
3. The use of the resources—e.g. the use of small whiteboards.
4. The use of questioning to elicit and promote reasoning.

A further issue that prompted comment was related to an aspect of student behaviour in the lesson. This was the phenomena of students guessing and doubt whether there was any underlying rationale or reason. A final observation was a general comment about the approach illustrated in the lesson, that there was a lack of mathematics in the example lesson.

In Chapter 8, I develop this analysis further and consider in more detail the processes of *noticing* and *attention* from a *social learning theory* perspective.

This discussion, although it is a small extract and selected as an *intensity* case, it is indicative of the processes that were taking place in the PD sessions in the other case study schools. What motivated much of the comment and judgement by teachers was with the expectancy of trying out the approach and making comparisons with the effective practice and pedagogy that they developed and used already. Assessments were being made about pedagogical elements, features and moves as well as the overall structure and pattern in the lesson.

In the next section, I look at how teachers took the models from the PD and implemented them in lessons.

6.2 How teachers used the PD materials: case studies

In this section, I describe how individual teachers used the PD materials. In particular, I consider how they take the ideas and approaches suggested in a PD session and implement them. My analysis was concerned with the nature and extent of the adaptations that teachers made to the models presented in the PD and their explanations for this. I described the case selection strategy, data collection and analysis approach in Chapter 4 (Section 4.3.5, p. 77).

The three teachers selected for the case studies were: Imran (Barrington), David (Boxton) and Cath (Norman Fletcher). In the following I provide a brief description of each teacher followed by an analysis of how they used the materials.

6.2.1 Imran

Background

Imran had been teaching for eight years and had been at Barrington four years (information about teachers was included in Chapter 5, see Table 5.4, p. 111). You will recall Deborah, the head of department, described the department as having a core group of four teachers who were worked collaboratively (Section 5.2.1, p. 109). Imran was outside of this core group, but Deborah described him as conscientious and hard-working.

Imran's strong work ethic was apparent: this was the impression I had, having observed and interviewed him on five occasions during the data collection, and from observing him in the four PD sessions working with the rest of the department.

Deborah explained that he found the behaviour of low-attaining groups challenging. However, she also explained, students that he taught in the higher ability groups tended to get good results.

In interview at the beginning of the project, Imran explained how he taught in a traditional teacher-centred way. He illustrated his usual approach in the following way:

> Most of the time we are doing [something like] SOH-CAH-TOA [mnemonic for trigonometry ratios] and I give them the formula and they just use it and apply it straight away.

Imran was quite anxious when I observed him teach on all five occasions although through the project he did become slightly more relaxed. I felt overall he found it difficult to relax with the students. He attempted to retain a degree of traditional formality and distance, for example, he would refer to members of his class as Mr. . . or Miss. . . in whole-class discussions. He did not have an informal rapport with his students.

It was the lack of accord between Imran and his student that was apparent. With this high-attaining group it was a palpable distance, but respectful. However, I imagined how that distance might have become more problematic with more challenging groups. Although, I observed Imran with only his year 11 set 1. Here I factor in the head of department's comment about Imran's difficulty with the behaviour of low-attaining groups that she made in my first meeting with her at the beginning of the project.

It is guardedly—out of awareness that what I write may be interpreted as a pejorative judgement—that Imran was not confident in his teaching or, in the theoretical language I use in this thesis, he had low teaching self-efficacy. I cannot be sure of the reason for this; whether the lack of rapport was a cause, effect or a related condition.

The PD session

Prior to the lesson that I analyse for this part of the research, Imran and his colleagues participated in a one-hour *introductory* PD session from the

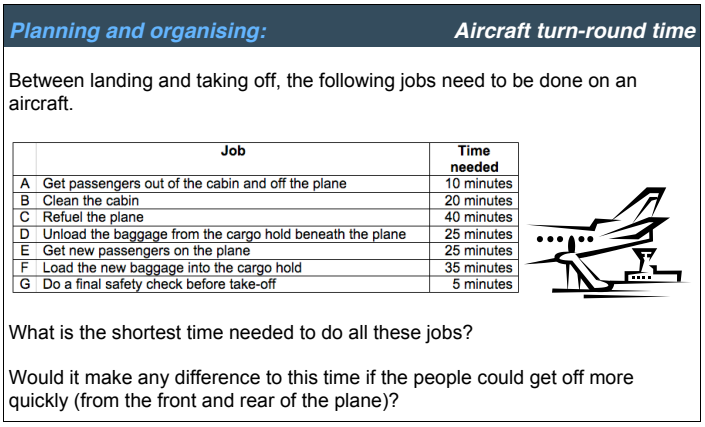
Questioning and Reasoning PD module. This had been led by Deborah, the head of department. The module handbook describes the aims of the module as to encourage teachers to think about the following issues:

- characteristics of questioning that encourages pupils to listen, think and reason;
- ways in which you might encourage pupils to provide extended, thoughtful answers, without being afraid of making mistakes;
- the value of modelling reasoning by 'thinking aloud' with your class (Bowland PD materials, *Questioning and Reasoning*, module handbook, p. 1).

I presented an analysis of another of the PD modules in Chapter 2, *Fostering and Managing Collaborative Work*. In that analysis, I described a two-level pedagogy within the PD. Each module has a pedagogic level, for example teacher questioning, group-work or formative assessment. There is also a practice-level component across all seven modules which focus on the teaching of problem solving (see Section 2.3, p. 14). In this module the pedagogic-level component is teacher questioning to promote the articulation of student reasoning. The problem solving tasks and lesson structure are organised around a student-centred lesson in which students have the chance to discuss and explore solutions and methods collaboratively. Similar lesson structures are evident in all the suggested lessons in all the PD modules.

In the *introductory* session of the *Questioning and Reasoning* module there are four 'activities'. *Activity 1* involves teachers thinking about the types of questions they use in lessons, *activity 2* involves teachers thinking about and discussing what types of questions promote thinking and reasoning. In *activity 3*, they watch an example lesson. This features examples of questioning to support reasoning and the lesson structure featured in the PD materials. In the final activity, *activity 4*, teachers plan their lesson for the *into-the-classroom* phase where they try a lesson out based on the ideas in the PD.

At Barrington, Deborah followed the PD guidance closely. In the first activity, which lasted 8 minutes, there was discussion by all teachers about types of questions that are used by teachers. In *activity 2*, there was recognition by all the teachers that contributed, that their questioning was closed and did not give students enough thinking time. They spent 15 minutes on this discussion before moving on to observe Gwen's lesson in *activity 3* which illustrated a problem solving lesson and highlighted the use of questioning to promote reasoning. In the final activity, members of the department split into three groups to plan their *into-the-classroom* lesson. I noted that in this discussion the lesson they observed in the PD acted as 'blueprint' for their own planning.



Planning and organising: **Aircraft turn-round time**

Between landing and taking off, the following jobs need to be done on an aircraft.

	Job	Time needed
A	Get passengers out of the cabin and off the plane	10 minutes
B	Clean the cabin	20 minutes
C	Refuel the plane	40 minutes
D	Unload the baggage from the cargo hold beneath the plane	25 minutes
E	Get new passengers on the plane	25 minutes
F	Load the new baggage into the cargo hold	35 minutes
G	Do a final safety check before take-off	5 minutes

What is the shortest time needed to do all these jobs?

Would it make any difference to this time if the people could get off more quickly (from the front and rear of the plane)?

Figure 6.2: *Aircraft Turn-round Time* problem.

Into-the-classroom lesson

The suggested plan, provided in the PD materials (see *Questioning and Reasoning* module, *into-the-classroom* phase), is as follows:

1. **Introduce the problem, and give time for individuals to think** (5 minutes);
2. **Collect initial ideas at the board** (5 minutes);
3. **Students work on the problem** (20 minutes);
4. **Whole class discusses the approaches being used** (10 minutes);
5. **Pupils have a second go at the problem** (10 minutes);
6. **Whole class reports on their reasoning** (10 minutes).

Imran adapted this, the PD materials suggested the use of one task in a one-hour lesson—Imran chose to use two tasks. The *Aircraft Turn-round Time* problem (see Figure 6.2) was used in the first half of the lesson and another problem (*Sharing Petrol Costs*) was used in the second half the lesson. I have included the first problem only as I used this in the analysis presented here. Imran used two cycles of a shortened version of the above lesson structure—one for each problem. I illustrate the lesson structure in Figure 6.3 (p. 144).

Imran explained in the interview after the lesson that he thought the problems were too easy and did not feature "enough maths", he had opted to include two problems. This was a correct assessment since the materials had been designed for Key Stage 3. I explained in the methods chapter how I had initially asked schools to work with Key Stage 3 classes. In the planning activity in the *Questioning and Reasoning Introductory* session, Imran explained to other members of the department that he planned to

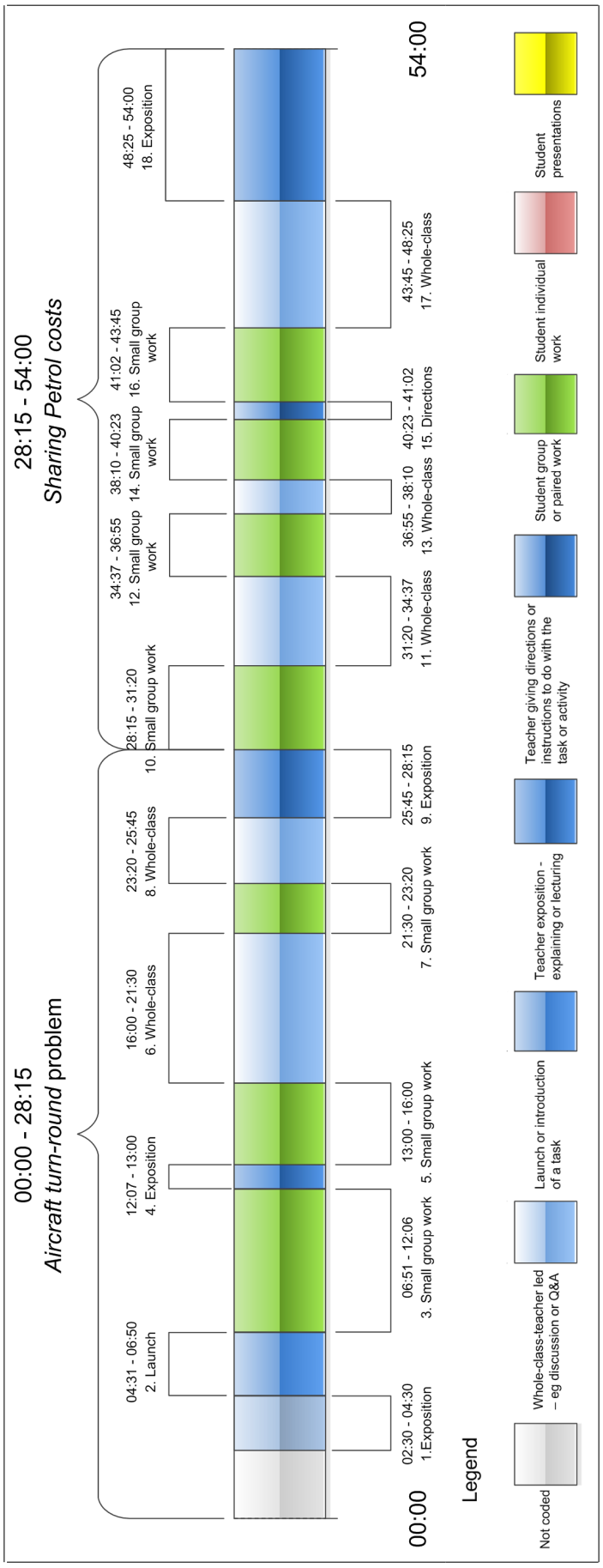


Figure 6.3: Lesson structure for Imran's lesson from the *into-the-classroom* phase of the *Questioning and Reasoning* PD module.

use the activities suggested in the PD in his *into-the-classroom* lesson. Therefore, using what he considered to be 'easy' problems was something he had planned to do well in advance of the lesson I observed.

The reason for this was not because he did not know his students or that he did not know that the problems were not going to be challenging enough. The way in which he planned the lesson and allowed time for students to arrive at answers in both parts of the lessons, demonstrated that he had awareness of the ability of his students. It was more likely that he did not feel confident in giving students longer periods of time to work on challenging problems and develop problem-solving skills. This is not a criticism of Imran's teaching, it is simply an observation.

In the lesson, he used the pedagogic structures and patterns suggested in the PD materials but shortened these in order to make the two problems more demanding by having a time limit on the activity. For the first problem, *Aircraft Turn-round Time* (see Figure 6.2), most of the class initially added all the times sequentially and soon realised that some tasks could be completed at the same time and where able to arrive at a plausible solution in a short time. The *Aircraft Turn-round Time* problem therefore became a more routine problem, the way in which students completed the *Sharing Petrol Costs* problem in the second half of the lesson was similar.

Students did not have a substantial period of time during the lesson to work on a demanding problem, where there was no single method or where the method was not obvious (see Schoenfeld, 1992). For these students the methods were more obvious because of their maturity, attainment and confidence. The lesson did not feature opportunity for students to make decisions about strategies and methods or evaluate solutions derived from different methods. I therefore characterized the lesson as teacher-centred, but without an initial demonstration of methods by the teacher. Imran had adapted the suggested student-centred problem-solving lesson into a more traditional form.

This interpretation was further supported when I considered, in more detail, the first half the lesson. Imran spent the first 2 minutes explaining that in the lesson he would be more interested in the students' ideas and strategies rather than their answers (*episode 1*, Figure 6.3). In the second episode, he distributed the *Aircraft Turn-round Time* problem (see Figure 6.2) and explained it was about saving the airline money. He asked the class to think about the problem individually for 3 minutes. Rather than looking at the problem, students began work on it in pairs (*episode 3*). After a few minutes Imran stopped the class. He told the class that although they were working well on the problem, they needed to think about how they would write it down. He asked them to think about writing their solutions down for 2 or 3 minutes (*episode 4*). However, the class resumed working on the problem in *episode 5* for 3 minutes much as before.

He explained how the lesson was about strategies. This could be considered an intention to develop students' problem solving skills. However, in practice, the level of demand of this problem for students at this level

and the amount of time students had to actually work on them, resulted in 'strategies' meaning something different. The 'strategies' that were valued in this lesson were the quality of written communication. This was evident in *episode 4*, when Imran stopped the class and asked them to think about how they wrote down their methods and explanations of methods and emphasised the importance of doing this.

The PD module preceding the lesson focussed on developing teacher questioning to promote student reasoning. I consider here, the nature of the dialogue and interaction between teacher and students. I draw on an example from *episode 8* (see Figure 6.3). Previously to this episode, Imran stopped the class in *episode 6* and asked students to explain how they were doing the problem. Students presented some of their ideas. Imran then asked the students about the effect of allowing passengers to disembark from the front and the rear of the plane. Students were given 2 minutes to work on this in *episode 7*, they talked about this in pairs or small groups. Imran stopped the class to review the question. He questioned the class about this issue (*episode 8*), asking them to explain their reasoning. The following is an extract from *episode 8*:

> Imran: OK, Alright [drawing the class' attention]. Let us come back to that last question again. Would it make any difference if we had people coming out of the plane from the front and the rear? Chloe, you were immediately saying it wouldn't, why is that?
>
> Chloe: Because it would still take 60 minutes to do the cargo, so it wouldn't make any difference.
>
> Imran: Can someone explain that a bit more please? [There is no response from the class] Who agrees with that, who agrees with Chloe? OK, Lea, please go on.
>
> Lea: Because, it doesn't matter how long that takes if some of the other jobs takes longer, then it is still going to take that much time.
>
> Imran: OK, that's fine, can anyone else add more to that, with regards... I want numbers, if I may use that word? Richard, can you explain that?
>
> Richard: Not really
>
> Imran: Who can explain that for us?

Considering the questions: 'can someone explain that a bit more please?' and 'can anyone explain that?' These questions are very similar to questions used by Gwen in the video example shown in the introductory session of the PD. It appears that these questions are open-ended and as suggested in the PD are aimed at promoting student reasoning. However, on closer scrutiny of the context of the questions, they are not as open-ended as they

first appear. The questioning begins with, 'would it make any difference if we had people coming out of the plane from the front and the rear?' This is a closed question in that it prompts the response 'yes' or 'no'. A response is offered and Imran asked, 'why?' Chloe responds with an explanation that it will still take 60 minutes.

There are similarities between the ways Imran uses the question to the **initiation-response-feedback** (IRF) routine (Sinclair and Coulthard, 1975). *Would it make any difference if we had people coming out of the plane from the front and the rear?*—**initiation**; there is then an unheard or implied *no*—**response**, then **feedback**: *Can someone explain that a bit more please?* This is more open-ended than an IRF routine with a **feedback** response of 'yes' or 'no'; Imran offers a more open-ended response which he appears to have acquired from the PD. Imran presses for a response to the open-ended question, 'can someone explain that a bit more please?' 'Who agrees with that who agrees with Chloe?' This prompts a response from Lea, who explains why it does not make any difference.

Instead of leading with an open-ended question, Imran began with an IRF sequence. This seems to have the effect of closing down the opportunity for students to articulate their reasoning, however Imran does attempt to recover the situation by introducing more open-ended questioning at the feedback stage. By this time though, he appears to have limited the range of responses and the extent to which students can respond, hence the lack of response to his questioning.

In the interview Imran explained that he used the lesson plan in the materials. He had watched the example lesson in the PD session and had used the guidance about the learning tasks. In terms of his overall motivation for teaching using a more student-centred approach to support the development of students' problem solving skills, he explained how he found it really challenging to do. He described how he was used to 'spoon-feeding', in other words teaching students methods by breaking them down into component parts. He attributed his approach and reluctance in using a student-centred approach as a consequence of his teaching self-efficacy.

> It's probably the case of not being confident enough to do this. I used to teach in London and most of the kids in my school were quite weak and from deprived homes, they just do not get it and you had to give them [a traditional and structured approach].

In sum, Imran adapted the suggested approach so that it was more like a traditional teacher-centred lesson, this was evident in the way he had used tasks, the lesson structure and in the type of classroom dialogue. The reasons for the adaptations are accounted for in Imran's self-efficacy in teaching using the suggested approach. He explained how he did not feel confident in his ability to use the suggested student-centred approach.

I now contrast the way Imran had implemented the suggested approach with David.

6.2.2 David

Background

David had been teaching for 8 years and had been at Boxton all that time, he was assistant head of mathematics. He was confident in mathematics—he had a degree in mathematics (or a mathematically related subject with 50% or more mathematics). My impression was that he was a confident classroom practitioner. He had good relationships with the students. I observed how he engaged in friendly but professional conversation with students in and out of lessons.

I got the sense that he was a confident in his teaching and this was supported by the school and the mathematics department's success.

Yet David articulated a perceived limit to the extent to which teaching could be changed. He said that problem solving was important, but it would require a change in the culture of teaching. He talked of a minimum expectation that students would be prepared for exams. This was an allusion to a teacher-centred status quo. However, I believed he had the confidence and skill, as a practitioner, to teach using student-centred approaches.

He explained that he included some problem solving as part of the introduction of new topics and as interludes in teacher-centred lessons. His misgivings were related to increased implementation of student-centred teaching more generally.

The PD session

David's lesson was preceded by the introductory session of the *Fostering and Managing Collaborative Work* module, the content of this session was described in detail in the analysis of the PD materials in Chapter 2. A further analysis of how the PD session was implemented was carried out in the previous section; there is a descriptive of summary of what happened in that session. (see Tables 6.2–6.4, pp. 130–132).

I briefly summarise some of the key features of that session here. It was led by Amy during a lunch break; there were five activities in the session. In *activity 1* all the department considered the '*How many teachers in the UK?*' problem, with the aim of experiencing a mathematical discussion. They spent 4 minutes on this before moving on to *activity 2* where they reflected on their discussion, this lasted four-and-a-half minutes. They briefly analysed their talk, whether it was *cumulative*, *disputational* or *exploratory* talk (the handout that accompanied this activity is included in the analysis of the PD materials, see Figure 2.4, p. 20).

In *activity 3*, the teachers watched Eve's lesson. In my analysis in the previous section, I gave a detailed account of the discussion teachers had after watching the lesson. There I concluded that teachers' attention was on aspects of what they observed, with thoughts to implementing the approach in the *into-the-classroom* lesson. *Activity 4*, saw the department involved

in planning how to implement some ground rules for productive group discussion. They tried to agree on rules that they could all use. Finally, in *activity 5*, they discussed how they would do the *into-the-classroom* lesson. They attempted to reach a consensus about how they structured the lesson and which problem they would use.

Into-the-classroom lesson

The lesson was based on the problem, '*How many teachers are there in the UK?*' The aim of the lesson was to estimate the number of teachers given the population of the UK is approximately 60 million. David worked with the same year 9 set 1 group for the five observed lessons.

There had been some further discussion about group-work after the PD session. David and other colleagues had become interested in using specified group rôles in the *into-the-classroom* lesson. The rôles were as follows: spokesperson (*gatekeeper*), *time-keeper*, *scribe* and *rule-keeper*. Each student, in a group of four, was assigned a specific function with someone to articulate the group's progress and achievements to the teacher and the rest of the class (*gatekeeper*). The *time-keeper* was expected to ensure that progress was being made and to set time-based targets. The *scribe's* function was to document what the group had done and the *rule-keeper's* function, unsurprisingly, was to ensure that everyone was doing as they were supposed to.

David and other colleagues had prepared a presentation about the different rôles and also prepared materials to help randomly assign group members to rôles. In addition to this preparation, David had also spent some of the previous lesson allowing his class to establish ground rules for discussion. 'Ground rules' was a focus of the PD session. The PD materials include a handout with some suggested ground rules for discussion and a suggestion that teachers may prefer to use the rules, or get classes to establish their own to provide a sense of ownership. I am not going to reproduce that handout here but refer back to it, as it was included earlier in this thesis when I presented an analysis of the PD materials (see handout 3, Figure 2.5, p. 21).

Time was spent at the beginning of the lesson organising the class into groups—David had also included a sophisticated method by which students of different attainment level were included in each group. Almost 10 minutes of the 50-minute lesson was spent organising groups, seating and allocating group rôles.

A lesson structure diagram for David's lesson is shown in Figure 6.4 (p. 151). David organised the class into groups in *episode 1*. He then gave the class time to think about the problem individually in *episode 3*. During the *working individually* episode many students were keen to get on with the problem and were discussing their ideas in whispered voices. David stopped the class and explained how each group member would be given a different rôle. David explained these roles in *episode 4*. Students then

worked in groups in *episode 5*. It was explained that each group would present to the whole class at the end of the lesson.

David stopped the class and explained how presentations were to be done and then each group presented their work in *episode 7*. After the presentations, there was a whole-class discussion (*episode 8*). David gave the class a further 5 minutes to develop their initial answers. David concluded by reviewing the lesson and suggesting an answer to the problem.

Overall, David used the lesson structure suggested in the PD materials, in the video of example of lessons, and the printed materials. He used the example task for the lesson and the ideas about promoting and organising student discussion: he asked the class to develop some ground rules for discussion in a previous lesson. He also brought in some other ideas which included group rôles and grouping in order to ensure a spread of ability.

This lesson was consistent with the ideas proposed in the PD. It used the same structure as that suggested in the PD. It featured time for students to think individually, to work in groups and to present their work to the rest of the class. David appeared to be at ease allowing students time to think about alternative approaches. The class was motivated and persevered with the task.

The lessons at Boxton were quite short at 50 minutes, students had just 5 minutes to work on the problem on their own and 11 minutes to work on the problem in groups of four. This gives some indication about the extent to which time had been committed to organising students into groups. The 10 minutes David spent on this was just slightly less than the time spent on working in groups on the problem. However, the student presentations revealed that students had thought carefully about the assumptions, estimates and reasoning. After the presentations, there was also a brief episode of 3 minutes where students had the chance to develop their answers.

The feature of the lesson, which was different from the ideas suggested in the PD, was the extent to which David managed the groups. This involved planning ahead and using ideas suggested by colleagues about the use of group rôles in the lesson. David had also made efforts to create groups with a variety of abilities. In all this made the time spent on organisation quite prominent in the 50-minute lesson.

Although David, in comparison with Imran, was more efficacious in the suggested approach and implemented the ideas consistently with aims of the PD, the investment in developing effective groups is important to consider further. On one hand, the mathematics department, on the whole, had been interested in group-work. It was likely this was the focus of the head of department over and above the aims of developing the teaching of problem solving. David's preoccupation could have reflected this. Alternatively, the interest in effective group-work was an attempt to reduce the risk in this kind of lesson. As David pointed out after the fourth lesson, "... when you take one of these lessons there is an element of risk-taking, because you don't really know where the lesson is going to go and how long things

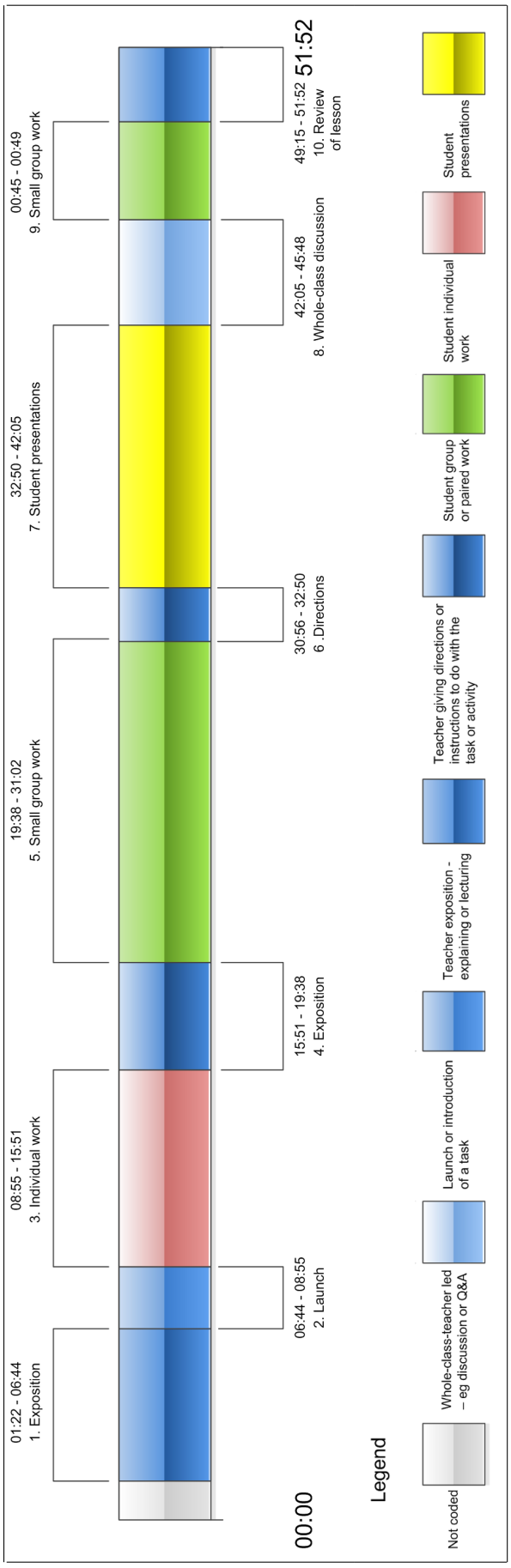


Figure 6.4: Lesson structure for David's lesson showing the organization of lesson *episodes* (minutes:seconds).

take…" Organising groups, as he did, was probably a way of managing the risk and promoting the productivity of the groups.

The second explanation, at least in part, cannot be ruled out. Therefore, David was self-efficacious in the suggested approach but there were limits to this and a point at which he needed to think about an approach to implementation that would make the approach work more easily with his class.

Additionally, David expressed concerns about a wider implementation of student-centred problem solving. This, he explained, required a big change in the "culture of teaching". He said the 'culture of teaching' involved the teaching of content. He said the most important aspect of teaching—what he described as a "minimum requirement"—is the teaching of mathematical content, "the kids need to know how to answer questions in exams". Secondary to this is what he described as the "thinking behind this". He expressed the view that if there was less emphasis on content, to give more time for thinking, then some of the content will get missed. He said however, that he does not just do 'chalk "n" talk', he encourages students to think for themselves.

Overall David was sufficiently self-efficacious to implement the suggested approach the into-the-classroom lesson in a way consistent to intentions of PD. However, there were limits to David's self-efficacy where there was an expectation of wider integration in practice.

The final case study contrasts with both Imran and David. Cath was new to teaching, I will describe how she used the materials in the next section.

6.2.3 Cath

Background

Cath was a *newly qualified teacher* (NQT) and therefore in the first year of her teaching career. She was a mature entrant to the profession. One of the schools she trained at had been involved with the filming of the final two Bowland PD modules. She explained her belief in the approach: she wanted to teach students to inquire and think for themselves rather than be relatively passive recipients of a series of methods. Her interest was linked to her exposure to the ideas as a trainee. She explained how she had observed her mentor teach using the Bowland materials. Cath was familiar with the ideas in the PD and was very positive about the approach.

The concern Cath expressed was with managing student behaviour. She accepted that as a new teacher—and new to the school—it would take time to get established. However, it was still a source of anxiety for her. It was therefore a challenge for Cath being observed and having her lessons recorded at the same time as she was establishing herself.

She also characterized her experience of her first year in teaching as learning how to do so many different things in the classroom. This was

important, and may seem obvious, but in contrast to Imran and David she was new to the profession and therefore did not have an array of developed pedagogical moves to implement. It was these which I understood her to mean that she was learning

My impression was that Norman Fletcher, of the four schools I observed lessons in, as part of this research, exhibited the most challenging student behaviour. One teacher explained to me that because of the size of the school, it is difficult to establish relationships with students—relationships that create a more positive culture. Norman Fletcher had around 2000 students, the teacher said to me that you just can't get to know all the students.

The PD session

The mathematics department at Norman Fletcher had completed the *Questioning and Reasoning* module. This was the same module that Imran participated in at Barrington. The session involves four 'activities'. It begins with a discussion between teachers about why questions are asked in lessons (*activity 1*). This was followed by a consideration of what is effective and ineffective questioning. Effective questioning, as portrayed in the PD promotes student to articulate their reasoning in the context of problem solving and beyond. The teachers spend 10 minutes discussing this in activity 2, using the handouts provided in the PD materials to document their ideas. In *activity 3*, the teachers observe a lesson. They watch Gwen's lesson based on the *Sharing Petrol Costs* problem. Finally, they plan a lesson for the *into-the-classroom* phase. The head of the department, Anne, asked members of the department to plan in pairs and use the same problem, *Sharing Petrol Costs*.

Into-the-classroom lesson

In the lesson (see Figure 6.5, p. 154), with year 8 set 1, Cath followed the suggested lesson plan closely and used the ideas from the video of Gwen's lesson shown in the PD session. She used the *Sharing Petrol Costs* problem.

As can be seen from the lesson structure diagram, there was an introduction (*episode 1*) followed by individual student work (*episode 2*). This was followed by a whole-class discussion in *episode 3*, where, as suggested by the plan, Cath collected students' ideas on the board. The class then worked on the problem in pairs in *episode 5*. There was another whole-class discussion in *episode 6*, in which the class talked about the ideas they had come up with. Students returned to working in groups in *episode 7*. Finally students presented their results in *episode 10*. This is the structure that was suggested in the PD materials and described in Imran's case study.

A noticeable difference between Cath's lesson and Imran and David's lessons was the amount of time that students had to work on the problem, working in groups or individually. Students in Cath's lesson had 50% of the

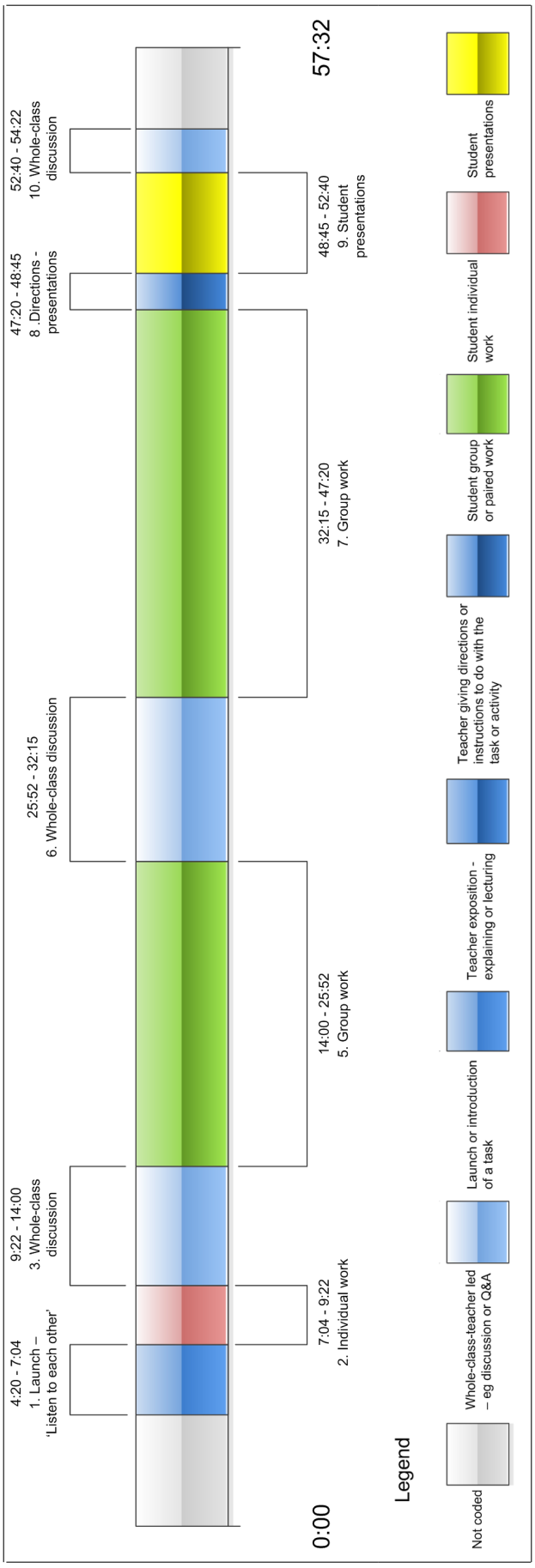


Figure 6.5: Lesson structure for Cath's lesson showing the organization of lesson *episodes* (minutes:seconds).

lesson to work on the problem in groups or individually. This compared to 42% in David's lesson and 35% in Imran's lesson. Cath allowed most time for students to work on the problem.

A further feature was the way in which Cath imitated a portion of the video example of the lesson. In the video, Gwen follows an episode of paired-work, in an early part of the lesson, with whole-class discussion. In this episode, Gwen asked students for their ideas about solving the *Sharing Petrol Costs* problem. As students explained the problem Gwen wrote a statement on the whiteboard to summarise students' ideas. Cath imitated this in *episode 3*of her lesson.

For much of the time students engaged with the task but in much of *episode 7* many students were working on a poster to present their ideas. At least half the class focussed their attention on decorating their posters and the production of lettering for the title. The solutions to the problem and evaluation of that solution were not evident.

One issue for Cath was the size of groups, she had six per table and this meant that students were not able to contribute to the groups when working together.

The key contrast between what Cath did with the ideas in the PD and what David and Imran did was that she implemented the materials without adaptation or modification. In Chapter 8 I consider explanations for this, including an explanation from a social learning theory perspective. Principally, the difference in the way the materials were used in the classroom is related to differences in levels of experience.

Although, this is not the only consideration in these results: the important feature is the adaptations that were made and seeking a coherent account of this from a professional learning perspective.

6.3 Summary

Having looked at how the PD materials were used by the departments in the previous chapter and how teachers used those materials in the present chapter, I have shown the effects of context and how departments find it difficult to sustain the implementation of the PD. In this chapter, I have looked how teachers engage with the PD materials, and make assessments about how they might implement the ideas in their classrooms. I follow this, in the final section, with consideration of how teachers actually implement the suggested approaches. This shows that experienced teachers adapt and develop the approaches to work for them. While the new teacher takes the ideas on trust, not having had the classroom experience to make an assessment about how the materials will work in class. I bring these ideas together and present a *social learning theory* perspective in Chapter 8.

In the next chapter, which is the last of the three results chapters, I present the results of how teachers changed as a result of participating in the PD.

Chapter 7

Changes in teachers' self-efficacy beliefs and practices

In this chapter, I present results in relation to the research question '*How do teachers' self-efficacy beliefs and practices evolve?*' The logic underlying the analysis presented in this chapter is the quantitative analysis of changes for all teachers involved, supported and enriched by consideration of individuals' changes from an analysis of qualitative data.

The first section relates to changes in teachers' self-efficacy beliefs, the second is concerned with changes in teachers' practices, the third deals with the practices teachers' found more or less difficult to adopt.

I begin with the quantitative analysis of changes in teachers' self-efficacy.

7.1 Changes in self-efficacy

In this section, I present the results of the quantitative and qualitative analysis of changes in teachers' self-efficacy. I begin with changes as measured using a standard teaching self-efficacy instrument (Tschannen-Moran and Woolfolk Hoy, 2001). This is followed by the results from the problem solving teaching efficacy instrument, which was developed for this study. Finally, I present the results of the qualitative analysis of how teachers considered their beliefs to have changed.

Changes in teachers' self-efficacy

Teachers' self-efficacy changed in one factor of the standard teaching self-efficacy instrument. The method used for this analysis was described in Chapter 4 (Section 4.3.6, p. 86). There was an increase in *efficacy for instructional strategies*; I present the details of this result in this section.

Table 7.1: Changes in teachers' self-efficacy for instructional strategies and student engagement using non-parametric tests.

Teaching self-efficacy factor	T	z	Probability (one-tailed) (p)	Effect size (r)
Instructional strategies	3.25	-2.572	.005	$-.429$
Student engagement	NA[1]	NA[1]	.500	-

Notes:
[1] *Sign test* used owing to Wilcoxon signed-test assumption violation. $n = 18$.

Table 7.2: Teaching efficacy factors median and ranges

	median		range	
Teaching self-efficacy factor	pre-	post	pre-	post
Instructional strategies	28.5	31.0	12	11
Student engagement	26.0	26.5	15	11

My hypothesis for changes in teachers' self-efficacy was that teachers' *efficacy for classroom management* would be unchanged and *efficacy for instructional strategies* and *student engagement* would increase (see Section 4.3.6.1, p. 88).

Teachers' *efficacy for instructional strategies* increased significantly from before the PD ($Mdn = 28.5$) to after the PD ($Mdn = 31.0$), $T = 3.25$, $p < .05$, $r = -.429$ (see Table 7.1 and 7.2). The effect is illustrated in Figure 7.1b (p. 159). (The raw data is included in the Appendix).

I further hypothesised that *efficacy for student engagement* would increase, however there was no significant change from before ($Mdn = 26.0$) to after the PD ($Mdn = 26.5$) (see Table 7.1 and 7.2). The effect is illustrated in Figure 7.1c (p. 159).

While *efficacy classroom management* increased significantly, ($M = 29.33$, $SE = .904$) to ($M = 30.94$, $SE = .698$), $t(17) = -2.022$, $p < .05$ (using a dependent t-test), this was not consistent with my hypothesis. I therefore accepted the alternative hypothesis in terms of *efficacy for instructional strategies* and but rejected the alternative in relation to *student engagement*.

The effect size in relation to *instructional strategies* ($r = -.429$) was of a small to medium size (Nolan and Heinzen, 2008, p. 547).

I discounted the effects of *classroom management* because it was not hypothesised. This was because I had no basis for attributing causality to the PD. It is also interesting to see that the change in efficacy for classroom management was also a result, in part, of the pre-PD data being heavily skewed (see Figure 7.1a). I further assumed the cause of this change was not

related to the PD based on accounts given by teachers that the suggested approach was more difficult in terms of managing classes. From my qualitative analysis, teachers were describing their teaching experiences, using the methods suggested in the PD, not as 'mastery experiences' and therefore I would expect them to be less efficacious in classroom management—or at least having the same self-efficacy in classroom management. I concluded that this change was a result of other effects and the skewed nature of the pre-PD data.

Changes in teaching problem solving self-efficacy

Teachers' *teaching problem solving self-efficacy* changed significantly from the beginning of the PD ($M = 120.56$, $SE = 3.486$) to the end ($M = 136.56$, $SE = 2.685$), $t(17) = -5.320$, $p < .05$ and $r = -.625$. This was found using a dependent t-test as described in the methods chapter. I therefore accepted the alternative hypothesis with a medium to large effect size. The effect is illustrated in Figure 7.2. The teachers' self-efficacy for teaching problem solving had increased significantly over the course of the PD.

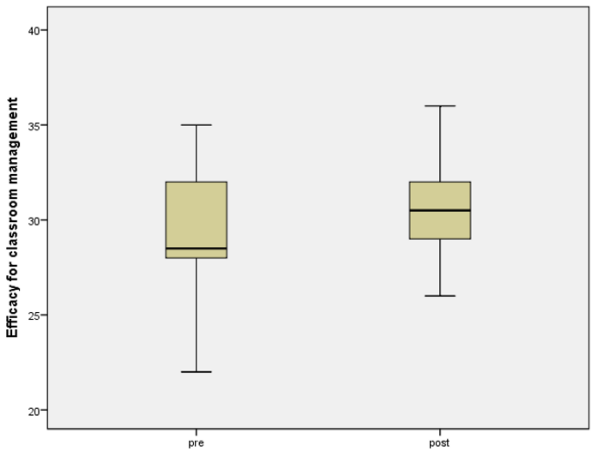
Qualitative analysis of changes in beliefs

I interviewed eight teachers through the project. The interviews took place after each of the five lesson observations. I also interviewed heads of departments (along with the teacher who led the PD session, if this was not the head of department) after each of the four PD sessions in each of the three schools. Teachers were asked how their perspectives on teaching and learning and in teaching problem solving had changed through the project. I was trying to establish what effect the PD had on the way in which teachers thought about their teaching. The way in which I carried out data collection and analysis were described in Chapter 4 (Section 4.3.7, p. 96).

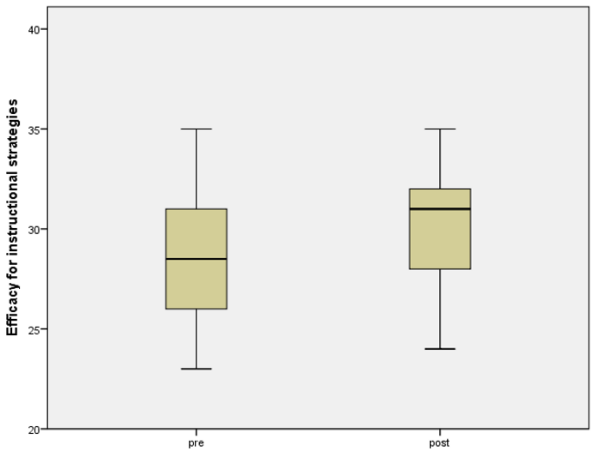
The quantitative analysis, in the previous section, showed all the teachers in the three departments and who attended at least three out of the four PD sessions ($n = 18$) had become more self-efficacious in instructional strategies and in teaching using approaches that support students' development of problem solving skills. The results I present in this section provide methodological triangulation for those results, but also explore some underlying processes of change in thinking and perspectives from the viewpoint of individual teachers.

I begin with two teachers whose espoused beliefs were consonant with the approach suggested in the PD at the beginning and remained similar throughout the project.

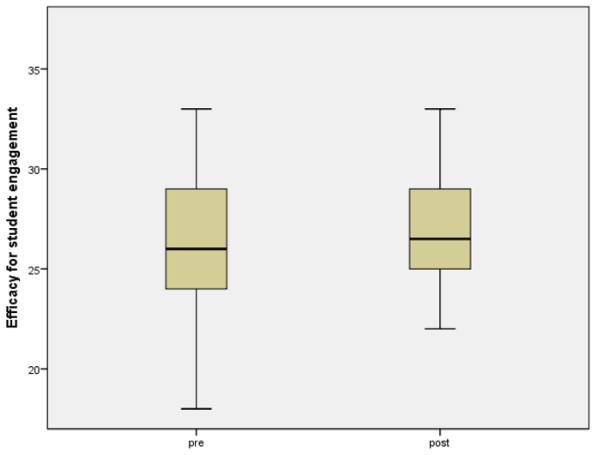
Barry (Barrington) and Adrian (Boxton) explained how the PD was consistent with approaches that they had aspired to use in their teach-



(a) Efficacy for classroom management



(b) Efficacy for instructional strategies.



(c) Efficacy for student engagement.

Figure 7.1: Boxplots of pre- and post teaching efficacy factors ($n = 18$).

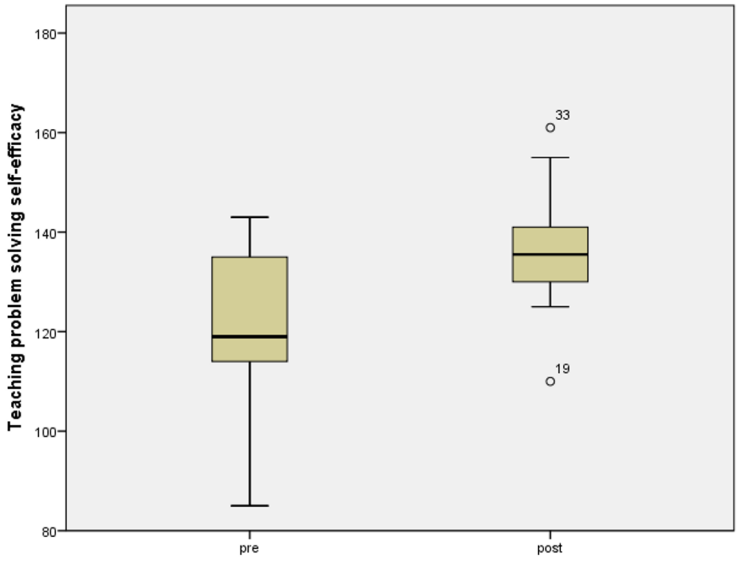


Figure 7.2: Teaching problem solving efficacy pre- and post boxplot.

ing. Barry explained, "I think one of the reasons we are doing this project is because I have been talking about how I would like to do more problem solving." For Barry the PD was an opportunity to try out ideas and use the approaches suggested in the PD to complement and develop his teaching in order to promote students' problem-solving skills. From this, it was reasonable to assume that Barry's beliefs about teaching and learning mathematics were consistent with the ideas advocated in the PD. However, in the latter part of this section, I show that Barry's beliefs about teaching and learning mathematics were more complex than is suggested in this part of the analysis: they were dependent on the character of the group he was teaching.

It is also important to note how Barry indicated a difference between what he aspired to do and what he actually did. He vocalised an ambition to use more problem solving, indicating that this did not characterize the totality of his practice.

Adrian explained that the PD renewed his interest in teaching the way he wanted to teach when he came into teaching—he was in his second year of teaching.

> I would say I have gone back to what I wanted to do when I first went into teaching. In a sense that I. . . you go in thinking I want to get them talking about it, seeing the need for it and then you get out into the classroom and you realise it's all about. . . or you perceive 'I just need to get control of this class, I need to get. . . ' But now I have done that bit, I feel like I can am starting to go back and think about 'why' a lot more (Adrian, lesson 4 interview).

Adrian explained that he had entered the profession and commenced a PGCE course with aspirations to encourage mathematical thinking and to build his future practice around this ideal. He explained how his training year and first year of teaching at Boxton had resulted in him having to compromise these aims considerably. He found that he had to teach in a traditional teacher-centred way in order to manage classrooms and student behaviour. Like Barry, he gave me the impression that the PD was an opportunity to develop an interest in alternative approaches to teaching. Something that Adrian had to suppress in order to make his rôle manageable at the very start of his career.

Through the project, neither Barry nor Adrian changed their view. They were consistently enthusiastic in the way in which they attempted student-centred lessons in the five lessons I observed. The comments that both Barry and Adrian made about the ideas suggested in the PD were after the fourth lesson I observed; this retrospective also supports the conclusion that these two teachers had not changed their perspectives through the project.

They continued to believe in the suggested approach, but in both cases the extent to which they would implement the ideas was dependent on the group they were teaching. This I will consider further in the next section when I present the results about changes in practice.

At Norman Fletcher, Cath, who was in the first year of her teaching career, explained how she thought the ideas presented in the PD were important. She said she had always felt it was necessary to give students the chance to become "independent learners". She had seen the PD and the suggested approaches in one of her placement schools in her PGCE year. Her mentor had been a contributor to the development of the PD materials. When she was asked if the PD at Norman Fletcher had influenced her views, she said not. She added that while she believed in the approach, she did not always do it because of the challenges it presented in terms of managing behaviour. This is consistent with Adrian's view about the first year of teaching and how he had focussed on managing classrooms using a traditional teaching format rather than introduce student-centred teaching, which was more difficult to manage. Cath was having a similar experience, she explained how she was using approaches that were making it easier for her to manage behaviour. The difficulty Cath was having with student behaviour was apparent in the lessons I observed. Cath was able to implement the suggested approaches but found it difficult to maintain control over the class. Although her classroom management skills developed noticeably over the five lessons I observed.

In terms of the other teachers' perspectives, David (Boxton), Christine (Boxton), John (Norman Fletcher) and Imran (Barrington) all articulated views that they were supportive of the ideas suggested in the PD. They articulated a belief that student-centred approaches were accordant with effective teaching: their espoused beliefs were consistent with the aims of the PD. However, of these four it was just David who claimed to use

student-centred approaches in his teaching. He explained that he frequently included an activity in his lessons that encouraged students to think more. While Christine, John and Imran said that they did not normally include student-centred approaches in their teaching.

Of the eight teachers, one teacher, Pete (Norman Fletcher), said that he did not believe in the value of the suggested approach. "The evidence I have seen, in my classrooms, is that I am not convinced that it is a good way of learning". This view became stronger through the project. At the beginning of the PD project, he was positive about the approach.

I accounted for this with the difficulties Pete had in the lessons I observed. He believed that students were behaving badly when they were given more opportunity to work on problems with less direction. In the lessons I observed, Pete was uncomfortable with the way students would not always appear to be engaged in the problems he asked them to work on. He was frustrated with this and would become quite angry at times.

Pete was the only example where a teacher had described a change in perspective or belief. Teachers, overall, did not express views that indicated a change in perspective. David for example explained:

> I don't think [the PD] has changed [my views about mathematics and the teaching and learning of mathematics] really. No, I don't think it has, no (David, lesson 4 interview).

However, they frequently acknowledged the challenge of teaching using the approach suggested. John explained how his views about teaching and learning mathematics had not changed as a result of taking part in the PD. He explained why, even though the ideas suggested in the PD were important, he avoided problem-solving approaches:

> I don't think it [view about teaching and learning mathematics] has changed particularly. I have always known that you have got to be able to do the applications of it. And try to help kids to understand... to see what they need to do as well as do it. I make a distinction between maths and sums. Maths is working out what the sums are. If you can't do sums, you can't do maths. If you can do sums you can still not necessarily do maths, you have got to work out what the sums are first. I often say it's like having a toolkit. Like a plumber goes to your house and he selects the tools he needs to do a repair. It's the same in maths you have got these tools: which ones do you need in order to approach this problem? And you may find that you use different tools to do the same job and that is not necessarily wrong. Teaching that [problem solving] is very difficult, we tend to shy away from it because it is difficult. Kids don't like it because they don't like being in limbo and not having that feeling of uncertainty. So it's a lose-lose. But we know what we need to do, we are just not very good at... we just need a bit of

> kick up the backside to get us to make it happen (John, lesson 4 interview).

Apart from one of the teachers, teachers' perspectives or beliefs about effective teaching and learning of mathematics had not changed. Their espoused beliefs, with the exception of Pete, were consistent with the aims of the PD. What this analysis reveals is that teachers, in spite of believing in student-centred teaching, did not always implement approaches consistent with their beliefs. There was a difference between their espoused beliefs and their enacted beliefs.

I described how I used data triangulation to validate the findings derived from teacher interviews (see Section 4.3.7, p. 96) by using data from interviews with heads of departments. While heads of departments were not asked directly about teachers' beliefs or changes in teachers' beliefs, they were asked what they thought teachers had taken from the PD and to describe the teachers that found it more or less difficult to implement the ideas suggested in the PD. In response to these questions (and other questions) heads of departments did not talk in terms of teachers' perspectives or changes in teachers' perspectives and beliefs, they did talk in terms of confidence.

Tony, the head of department at Boxton explained that he thought that members of the mathematics department were more confident and motivated in using more student-centred approaches:

> So there is less of a... what is the word? Afraidness... there is more of a willingness to try, rather than a fear-factor like before ... the fear factor is lessened, I wouldn't say it has gone (Tony, post PD 2 interview).

Similarly Deborah characterized change in terms of confidence.

> ... I think what it has done, it has given us the structure and the time to focus on it in a way that we might not have done had we not got these sessions... So I think it has given us the freedom and, as I say, the structure to talk about it a lot more and to talk about it as a team... I think that is the effect of it, we have done more of that sort of activity with more confidence... (Deborah, post PD 2 interview).

This is consistent with the quantitative analysis of self-efficacy, where all teachers who participated in at least three PD sessions had increased self-efficacy in teaching approaches that support students in developing problem-solving skills. Here, two of the three heads of departments highlight this, in terms of less fear and increased motivation, and that teachers have taught using the suggested approach with more confidence.

Teachers did not talk about changes in confidence or motivation through the project, but referred to self-efficacy as a barrier to implementing the suggested approaches. Referring back to John's comments:

> Teaching [problem solving] is very difficult, we tend to shy away from it because it is difficult. Kids don't like it because they don't like being in limbo and not having that feeling of uncertainty. So it's a lose-lose. But we know what we need to do, we are just not very good at... we just need a bit of kick up the backside to get us to make it happen (John, lesson 4 interview).

His explanation for not wanting to teach in ways that support the learning of problem-solving skills were in terms of the difficulty and that 'extrinsic' motivation was needed to encourage—perhaps even force him to do it.

Barry, who I had previously described has having beliefs that were aligned with the aims of the PD and was willing to use the approach with his high-attaining year 11 group, was more reluctant to use a student-centred problem-solving approach with other groups.

> I have got a set two that I am pretty much teaching in parallel with this lot, who are the kind of set two that are mostly going to do higher tier. And to be honest with you, on the whole, I have steered away from doing these kinds of task with them. Just because I know it would be much more painful... They go off task very quickly... One of the things you are often wanting to do is get them quiet and get them working. (Barry, lesson 4 interview).

Like John, his reluctance is related to having the confidence that it will 'work' in relation to classroom and behaviour management. It is a self-efficacy issue: the belief the teacher has in the degree of success they will have in the application of a set of actions.

Barry's perspective on teaching and learning was coherent with the ideas suggested in the PD. His self-efficacy beliefs in relation to the suggested approach were in high in the context of his year 11 set 1 but lower in the context of his set 2 group. This is a fine-grained scrutiny of Barry's self-efficacy beliefs. His head of department's overall judgement was that he, with other members of department, was more efficacious in the suggested approach than Imran, Brian and Danny.

> I would have said Barry, me Cheryl and Lynne do these activities [student-centred problem solving lessons] with a certain degree of confidence, because I think we like to try things like that. And we don't mind if it goes wrong. Maybe we have the relationships in the classroom to be able to do that (Deborah, post PD interview).

Deborah's assessment was that self-efficacy (confidence) is important in terms of teachers' motivation in implementing student-centred approaches. She also relates confidence, motivation (self-efficacy) to relationships with

students: having the confidence to cope with things going wrong. I infer from this that Deborah thought that if a teacher had a good relationship with individuals in a class, then if the teacher tried something and it did no go smoothly then then teacher could cope with this more easily.

David made a similar point to Barry. He says that he was confident implementing the ideas with a year 9 set 1. This afforded him greater margin for error if things were not going well, because they were more patient. His view was consistent with the notion that a teacher could be more confident with a student-centred approach with a higher attaining group.

Furthermore, David made a generalisation about the approach in relation to existing practices and the source of teachers' reluctance.

> . . . I think it's a big change as well, in terms of the change in the kind of culture behind teaching and it's not something that is going to happen immediately. I think it is important to try and get kids to think for themselves, which is kind of the main thrust of the PD, I suppose. But it is tough really and especially, I think, because when you take one of these lessons there is an element of risk-taking, because you don't really know where the lesson is going to go and how long things take. So, I think I have been lucky in terms of having the top set, because I think they are very patient but with a lower-down set the patience isn't necessarily there. So for a normal teacher on a normal teaching day you are faced with, 'shall I take this risk with this lower set or should I not?' The easy way out is just to say, 'I will leave it' (David, lesson 4 interview).

David did not see beliefs about teaching and learning mathematics as a barrier to teaching in the ways suggested by the PD. David explained the barriers in terms of existing cultures, 'risk-taking' and not knowing how the lesson might play out. The consideration of the attainment-level of the group also suggests that the barriers to teaching in student-centred ways are related to student behaviour and managing behaviour. This links to self-efficacy beliefs, that resistance to teaching can be explained in terms of the beliefs teachers have in the extent to which they will be successful with a teaching approach. Success in David's terms appears related to classroom management and student behaviour.

Christine explained that she thought *using and applying* mathematics was becoming increasingly important. I asked her specifically if her views about the way students learn had changed, she said that it had shown her that low-attaining students could "access the tasks very well" as a result she said she felt more confident using the kinds of tasks presented in the PD with lower-attaining groups.

> I think it has probably opened my eyes a little bit because some weaker kids can actually access the tasks very well. I do have

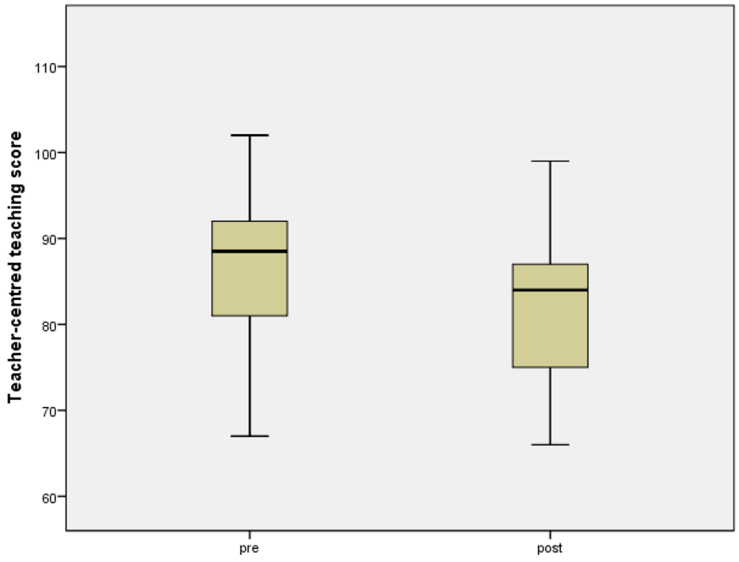


Figure 7.3: Teacher centred practices pre- and post boxplot.

> high expectation of kids anyway, I have high expectations of my bottom set (Christine, lesson 4 interview).

In sum, teachers' perspectives or beliefs about teaching and learning mathematics remained similar throughout the PD project. Furthermore, teachers' beliefs did not represent a barrier to teaching in the suggested approaches. Two of three heads of departments described the effects of the PD in terms of increased self-efficacy. This was consistent with the quantitative analysis of teachers' self-efficacy in the previous section. Teachers' themselves did not describe the impact of the PD on their own confidence and motivation. However, their comments revealed how self-efficacy was important in implementing student-centred approaches.

In the remaining sections of this chapter, I present the results of changes in teachers' practices.

7.2 Changes in teachers' practices

Overall changes to practices

For the teachers in the sample ($n = 18$) their self-reported teacher-centred practices reduced over the course of the PD, pre- ($Mdn = 88.5$, range = 35); post, ($Mdn = 84.0$, range = 33), $T = 8.00$, $z = -1.729$, p(one-tailed) $< .05$ and $r = .287$ (see Figure 7.3). This was a small to medium effect. The raw data is included in the Appendix.

Qualitative analysis of changes in teachers practice

Teachers were asked, when they were interviewed after the fourth lesson, '*as a result of taking part in the PD what do you think has changed in the way you teach?*'

Barry described how he liked to let students struggle with problems more:

> I quite like just letting them stumble around. I think one of the things I have become conscious of... I don't like to tell them stuff as much. So I much rather they stumbled around for a bit: having a think about it themselves. I suppose if you came to me five or six years ago it would be all about doing an example that picked out all the things where they could go wrong.

Imran made a similar point:

> I tend to withhold more and think... than give. And they just get on with it, because I do that now most of the time because I see that holding back a little bit sometimes and getting them to think, then when they struggle I help them. I help them more that way than the way I would normally do it... just give them what they need to solve the problem with and then get on with it. I see this generates more thinking from their end and doing that, it makes their maths a lot better.

David said how he was thinking about students' thought processes in lessons, although he said it was something he was aware of already, he was giving student thinking more focus and encouraging students to explain their thinking more.

Adrian explained how he was less scared of having a noisy classroom and had changed the desk arrangement in his room so that it was organised for group-work all the time. He said that there was no way he would go back to teaching in rows. Christine explained that she was doing more group-work with one of her year 11 classes and described how she had them prepare and teach a revision topic in groups. Of the three teachers interviewed at Boxton, Adrian indicated his teaching had changed the most.

Cath, who was in the first year of her teaching at Norman Fletcher, explained how she could not really talk about changes to her teaching: she was too new to it. She said she was learning all the time, meaning that she was developing classrooms skills, pedagogic knowledge and establishing relationships with students. John was unable to say whether his teaching had changed as a result of the PD. Pete, said that he was using more open-ended questioning in his teaching, he said he was not always immediately giving students answers but encouraging them to think about the problem further.

Heads of departments were also asked about changes in teaching. At Boxton it was believed that teachers were making more use of discussion and collaboration in lessons:

> I consider there is far far more group-work going on now than I can recall, for one thing. [At]... Key Stage 3, more so than year 10 and—well, at Key Stage 3 it is more of a accepted practice, where prior it was a sort of novelty. You know what I mean, it is part of practice, you didn't see that much of it before (Tony, Head of Mathematics, Boxton, *interview after third PD session*).

At Norman Fletcher the head and assistant head of department were not sure if teachers' practices had changed. They explained that as a result of negotiations with one of the teaching unions, they were limited in the extent to which they could observe lessons. They had no evidence from which to judge whether there had been an effect on the way teachers' taught.

At Barrington, Deborah the head of department, believed that there was more problem solving included in lessons, particularly by her, Lynne, Cheryl and Barry. She also described some observations that had been made by the school's leadership team:

> [W]e have had, with the imminence of OFSTED... management have been doing quite a lot of out-and-about and they've commented on how much discussion they see when they go into maths classes... how much discussion and problem-solving and kids talking about their work. In a way that I don't think they might have seen.

The changes described here include, greater use of group-work, encouraging students to persevere with problems and more open-ended questioning. This is consistent with the quantitative analysis in the previous section. This revealed a small to medium effect in terms of teaching becoming more student-centred over the course of the PD.

In the next section I look at what aspects of the PD were more or less difficult to adopt.

What practices did teachers find difficult to adopt?

In order to investigate the practices teachers found difficult to adopt, I considered what they believed the challenges were in teaching in the ways suggested by the PD using the same analytic approach I had used in the study of teachers' changes in self–reported practices.

The most common response was not aimed at a particular aspect of practice, but was related to concerns about student behaviour, or more specifically, the possibility that a student-centred problem-solving approach makes managing behaviour more of a challenge. For example, John from Norman Fletcher described the challenge of the suggested approach in the following way:

> You risk a loss of control. You have to be much more comfortable with letting there be recurrent chaos in the classroom. You can't say 'shut up and do this' because they are not going to shut up they are not going to stop doing that. It's the essential part of it—a lot of it is collaborative, a lot of it is learning from each other. A lot of it is there isn't a right answer, and that is very much a more uncomfortable position for both the students and the teachers to be in. You have to learn to manage your discomfort.

John was observed teaching a lower-attaining group. He found the behaviour of the group very challenging and explained that the experience had been negative. On the other hand Barry from Barrington taught a high-ability year 11 group through the project and had a much more positive experience. Although when asked about the challenges in teaching in ways suggested by the PD he imagined and described the problems he thought he might have with another more challenging group.

> They go off task very quickly. You could see even with this lot [the year 11 top-set group], some of them were drifting. With my set 2 particularly, they would be drifting in minutes. So I wouldn't. I suppose what I would have to do is scaffold the lesson a bit more, make it a bit more structured (Barry, interview after lesson 4 observation).

This supports the idea that teachers consider the effectiveness of teaching as related to effective classroom management.

John spoke of "recurrent chaos" in a student-centred lesson and he talked in terms of coping with disorder. Barry suggested that with his set 2 class he would need to "scaffold the lesson a bit more" and "make it a bit more structured" which means making it more teacher-centred.

Cath, the newly qualified teacher at Norman Fletcher, explained the challenges of teaching using the suggested approach was she was "never quite sure what was going to happen" and there was no "set pattern" to follow.

Pete from Norman Fletcher talked about the "routines" of a "normal" lesson with which students know what is expected. Pete also elaborated on the idea of structure. This term has been used in this thesis to analyse the arrangement of episodes in a lesson. Pete, like other teachers, used 'structure' to characterize teacher-centred teaching. Pete contrasted the way he usually teaches with the approach suggested in the PD as follows:

> In a normal maths lesson, I can say, 'right, I need you to get to—you are not making enough progress, you are not settled—I need you to get to at least question two or you are not going to break on time.' With this, I can't say that because there isn't a right or wrong. There isn't a question one and question two. I

> can't say you must get to this stage because there isn't a stage to get to... I think that complete lack of structure makes it a bit more tricky.

There were specific aspects of the PD that teachers found more or less difficult to adopt. For example, allowing students to sit in groups, and giving them chance to think more before intervening. Overall, what teachers considered to be difficult was in terms of being effective in classroom and behaviour management with all students rather than just those high-attaining few.

Development of teachers' practices in the observed lessons

In the final part of this chapter, I look at how teachers changed within the observed lessons. I consider how teachers developed in the teaching of student-centred problem-solving within lessons that were devoted to the approach.

The research was designed in order that teachers could be observed teaching problem-solving lessons at five points through the project in order to identify how their approach to teaching problem solving had developed over the course of the PD. Two of the lessons were planned in the introductory session of each of the PD modules. These were the *into-the-classroom* phases of the PD modules and were the second and fourth observed lesson. Six of the teachers were observed five times. These were Barry and Imran from Barrington; David and Adrian from Boxton; and Cath and Pete from Norman Fletcher. The aim was to consider how their teaching of student-centred problem solving developed through the project.

In this, I used the three teachers from the case studies in the previous chapter. These were: Imran (Barrington), David (Boxton) and Cath (Norman Fletcher).

A lesson diagram for each of the teachers' five lessons is shown in Figure 7.5, 7.6 and 7.7 (pp. 174–176). It is worth bearing in mind during the presentation of these results that 'blue' represents teacher led episodes and 'green' represents student group work. These are included in the legend for each set of diagrams. However, the blue and green elements are the focus of this analysis: how much teacher-led or group-work activities are there? And, how are these arranged in the lesson? How does the pattern change from lesson-to-lesson?

I begin with the set of lessons I observed Imran teach and then compare and contrast this analysis with the patterns evident in David and Cath's lessons.

In Imran's first lesson (see Figure 7.5a, p. 174). He uses two sets of problems—he has two related mini lessons within a single lesson. Each of these featured group-work interspersed with whole-class discussion. After the PD session, Imran uses the same lesson structure with two mini lessons

(Figure 6.3). However, there was less time for group-work since there were more interjections for teacher exposition or whole-class discussion.

In lesson 3, he let students have much more time working independently and collaboratively on the problem (Figure 7.5c). He gave the class a set of problems, taken from past examination papers (see Figure 7.4) and allowed them to get on with problems. This differed from a traditional lesson only in the fact that Imran did not explain the methods to use at the beginning of the lesson. The set of problems, as illustrated in Figure 7.4, are routine problems, where there are a limited number of ways in which the problems can be solved. They are not the sort of problem suggested by Schoenfeld, as a task where it is not obvious which technique or method to use to solve the problem (Schoenfeld, 1992). Although not explaining methods does set up this situation, students would simply have to look up the 'method' to use.

Lesson 4, followed the second introductory PD session, in this lesson Imran followed the suggested ideas and plan more closely (Figure 7.5d). He allowed more time for group-work. In lesson 5, the pattern of the lesson is similar to lesson 1 and 2. There were two tasks and periods of group-work were interspersed with teacher-led plenaries.

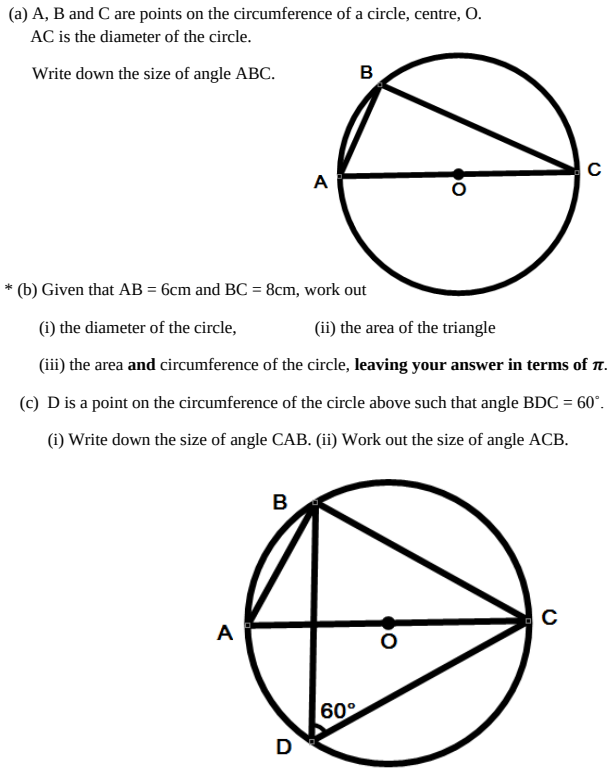


Figure 7.4: Imran, lesson 3, example of Circle Theorem problems.

Overall there was no overall pattern which revealed how Imran's teaching developed over the programme. However, there was a relationship between the amount of group-work that Imran permitted and the type of

task. The more the task would not keep students occupied and engaged the more plenary sessions he included. I refer back to the case study in the previous chapter to make this finding. In addition, it can be seen how in lesson 3 (Figure 7.5c), Imran gave the students a set of revision problems they could get on with. In contrast, in lesson 2 (Figure 6.3), Imran thought the tasks were two easy and therefore interjected and used a two-mini-lesson strategy.

Turning to David's lessons (see Figure 7.6, p. 175), lesson 2 and lesson 4 were implemented in a way that was consistent with the lesson plan included in each of the PD materials. In lesson 1, 3 and 5, where David was asked to teacher a problem-solving lesson of his choice, there was no evidence of a pattern of development.

In lesson 1 (Figure 7.6a), David spent time at the beginning of the doing some revision on Pythagoras' Theorem, before getting the students to work on a puzzle which required its use to solve a geographical puzzle. The lesson required students to practice the use of a mathematical technique but was not a problem solving lesson, as I discussed above—there was not a range of methods that could be used to solve the problem. This is not critical of David but an observation based on the definitions I am using here.

Lesson 3 (Figure 7.6c) coincided with a non-uniform day. In this lesson the task was open-ended and required limited mathematical thinking. Students were asked to make nets and construct 3D shapes to make an 'interesting' object. After David carefully organised the class into groups and allowed them to get on with the tasks which they enjoyed doing but it contained limited mathematical challenge.

In lesson 5, (Figure 7.6e). David spent time organising groups and group roles before students worked on a problem which involved them having to work out what the largest cube they could make from an A4 piece of paper. David asked them not to use trial and error and wanted them to model and predict.

Like Imran, the way in which David structured the lesson was related to the task and the extent to which the he thought students might struggle and not be occupied by. David, in lesson 3 and 5, found tasks that he could give the students to get on with for extended periods and also were appropriate to the context. In this respect lesson 3 was on a non-uniform day, the students were excited and were not in the frame of mind to work patiently on a challenging problem. The task clearly met the requirement of giving the class something to do, but had limited mathematical challenge.

Cath's series of lessons similarly did not reveal a pattern that showed development in the teaching of the approach suggested in the PD. However, it does reveal that Cath, unlike the other teachers, used the ideas and suggested lesson plans in lessons 2 to 5 (Figure 7.7, p. 176); she used lesson plans and tasks from the PD materials in each of these lessons. While Imran and David were using their experience to judge what tasks to use and how to implement them, Cath, as a new teacher, had relatively little of these experiences and therefore implemented the approaches without

pre-judgement.

The analysis of a series of lessons did not reveal much about the change process, since there were so many different factors influencing the design and execution of each lesson. There too many confounding variables. However, this analysis reveals something about teachers' attempts to change in practice and the results presented here have to be taken alongside the analysis of Imran, David and Cath's use of the PD materials in the previous chapter.

This longitudinal analysis shows repeated contextually-specific attempts to implement the ideas or similar ideas suggested in the PD. One key issue is the amount of time teachers allow students to work on a challenging problem-solving type of task. The more challenging the activity, particularly in respect to it being open-ended, the less time teachers allow their students to work on them. Or, they try and teach them how to solve the problem in advance. The situation was slightly different with the new teacher who was more willing to try the suggested ideas unfettered. I discuss this further in the next chapter.

7.3 Summary

In this chapter, the results of this research have been presented from the perspective of *change*. That is, changes in teachers' beliefs and changes in practices: the practices teachers adopted as part of the PD and finally the effects of the PD on students.

In terms of changes in teachers' beliefs, this research shows that teachers' self-efficacy in teaching using a student-centred problem-solving approach had developed. This was based on the analysis of teacher survey data and also supported by the qualitative data, in particular the comments made by two of heads of departments. Although, teachers talked in terms of developing confidence in the suggested approach.

It was also shown that while the PD may have contributed to developing teachers' self-efficacy, there seemed to be little effect on teachers' beliefs about the teaching and learning of mathematics.

The analysis of teachers' self-reports about their teaching before and after the PD, along with interview data from teachers and heads of departments, shows that there had been some small changes in the ways teachers' taught. Their teaching had become more student-centred. Although, I am alert to the fact that this may mean that teachers adopted some features such as group-work and questioning into a predominantly teacher-centred approach. The extent to which teachers offered problem-solving types of lesson was so much dependent on the confidence and attainment level of the group.

In the next chapter, I discuss these results and those of the previous two

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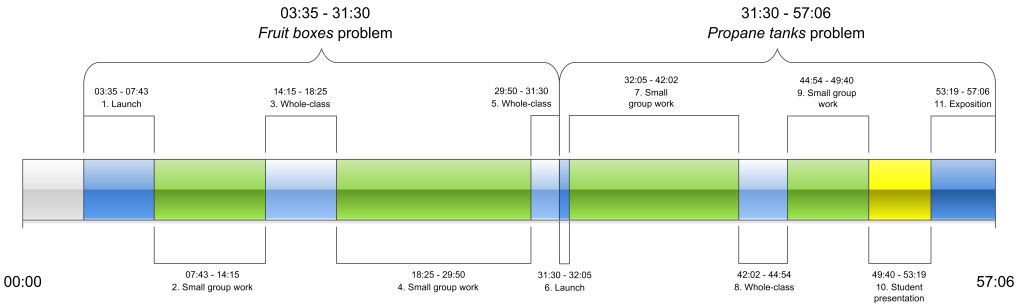
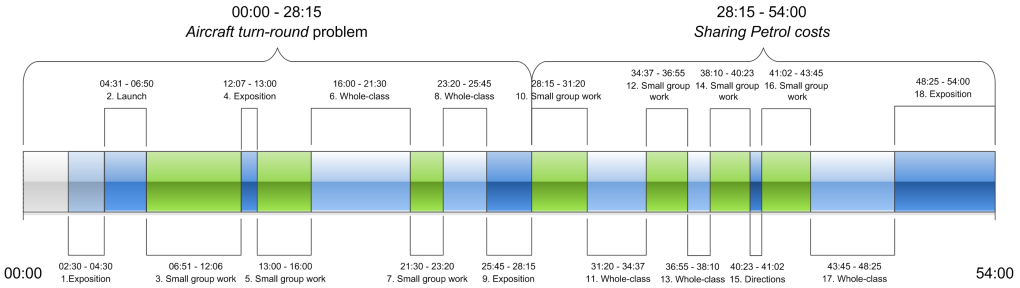
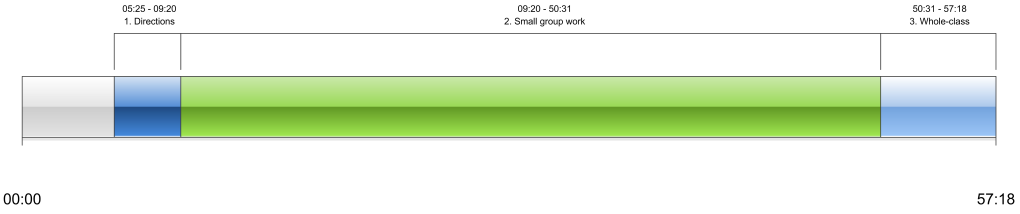


(b) Lesson 2.



(c) Lesson 3.



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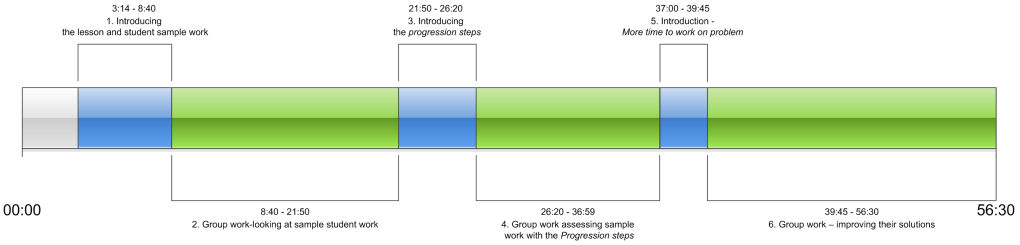


(e) Lesson 5.

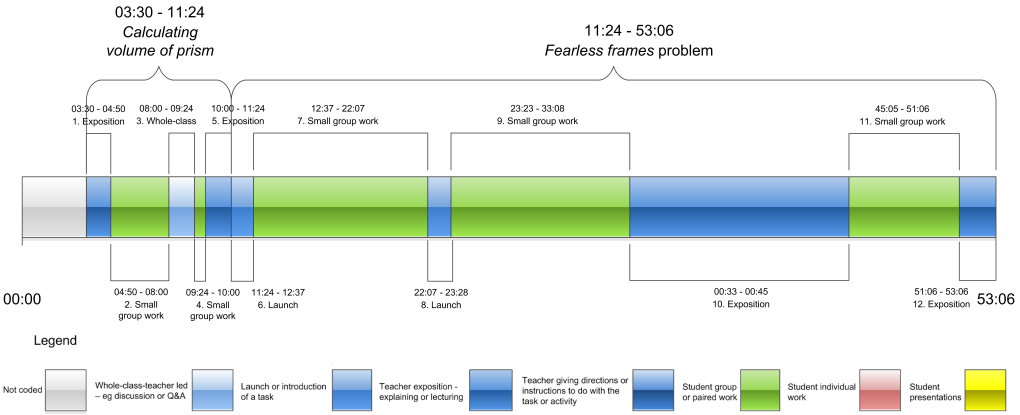
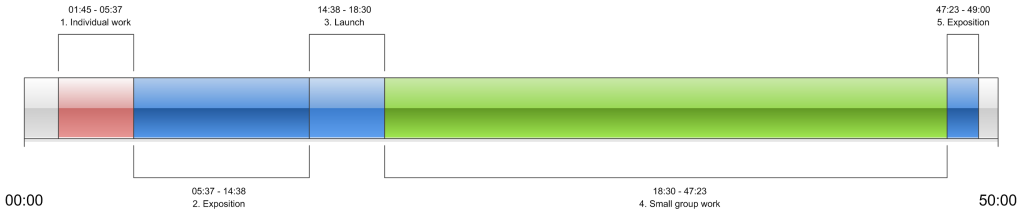
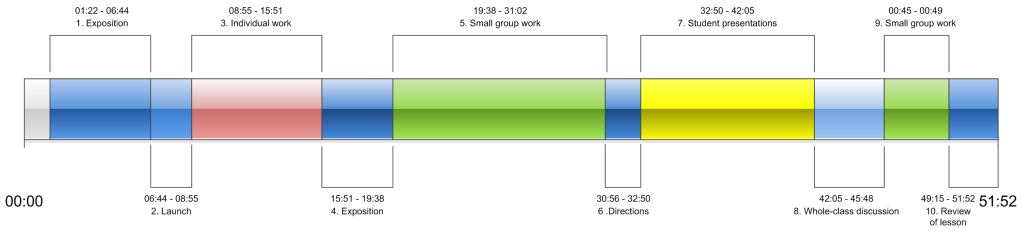


Figure 7.5: Imran, Barrington, lesson timelines for observed lessons.

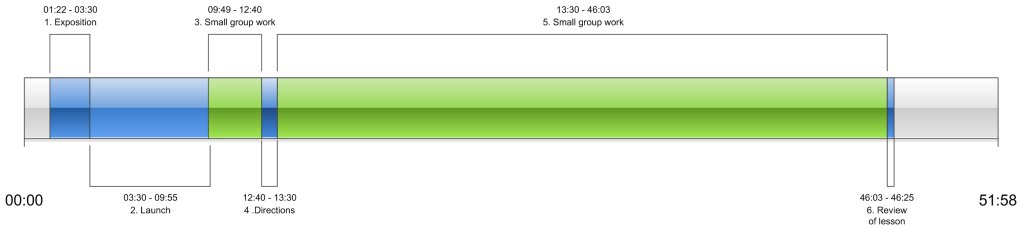
(a) Lesson 1.



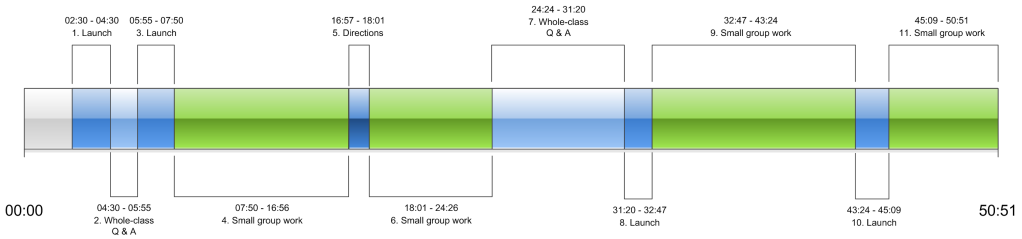
(b) Lesson 2.



(c) Lesson 3.



(d) Lesson 4.



(e) Lesson 5.

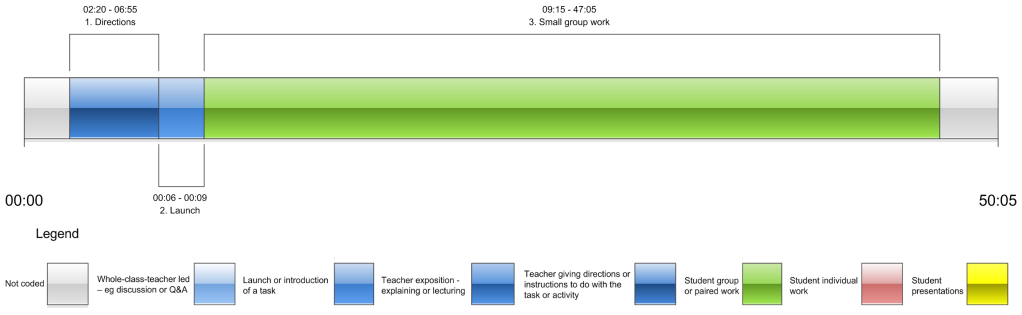
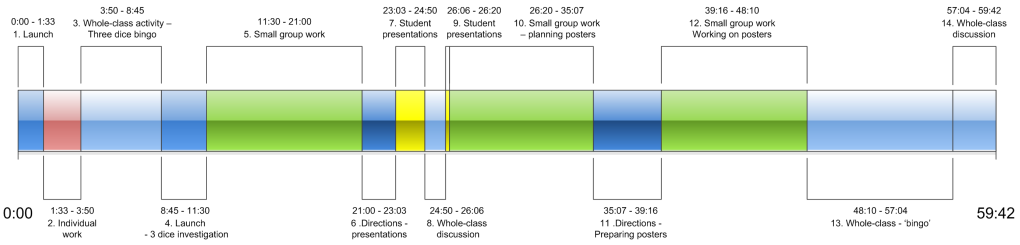
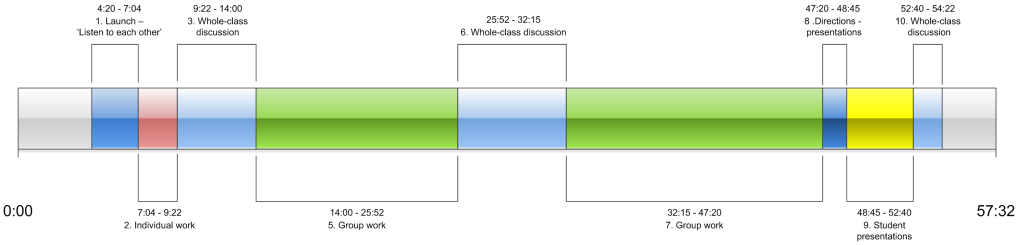


Figure 7.6: David, Boxton, lesson timelines for observed lessons.

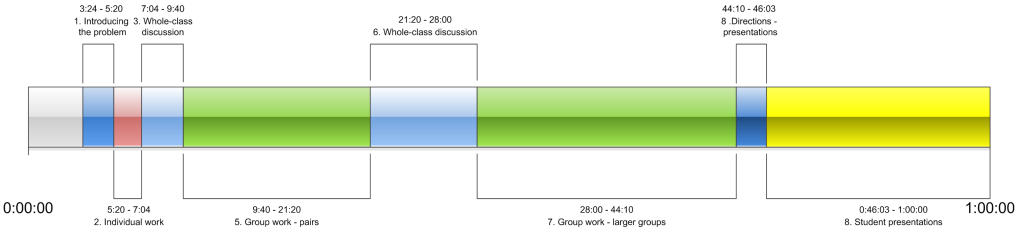
(a) Lesson 1.



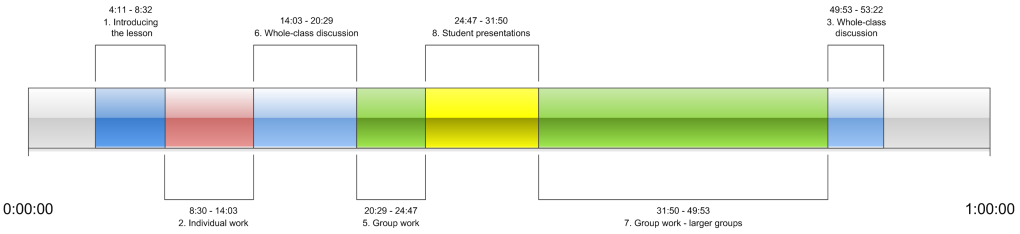
(b) Lesson 2.



(c) Lesson 3.



(d) Lesson 4.



(e) Lesson 5.

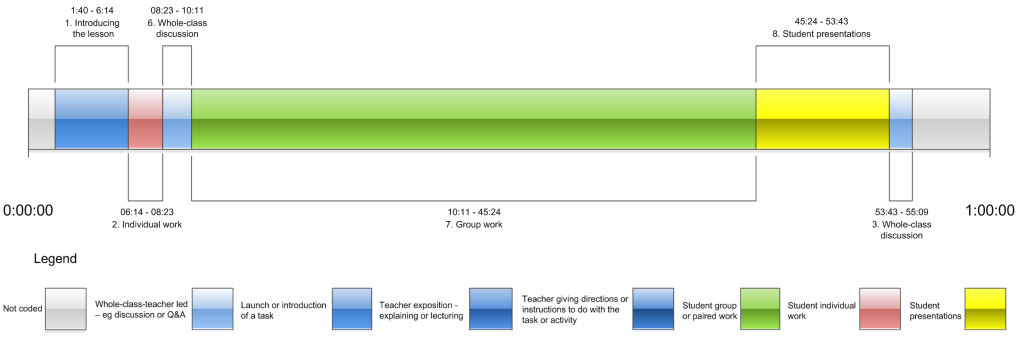


Figure 7.7: Cath, Norman Fletcher, lesson timelines for observed lessons.

chapters and offer an interpretation of these results from a *social learning theory*.

Chapter 8

Discussion

In this chapter, I discuss the results presented in Chapters 5, 6 and 7. This is organised in a similar way to those chapters and corresponds to the research questions:

1. How do teachers use the professional development materials: what do they attend to and why?
2. How do teachers' self-efficacy beliefs and practices evolve?
3. Which practices do teachers find easiest or most difficult to adopt? Why is this?

I begin with a discussion of how the PD was used with departments as the focus. Following this, I discuss results in relation to how individual teachers used the PD. In the final part of this chapter, I look at the way in which teachers changed drawing on both qualitative and quantitative analysis.

Overall, I take the results from the multiple studies and interpret the learning processes and changes in teachers' self-efficacy, beliefs and practices from the perspective of *social learning theory*.

8.1 How the PD was used

Here, I discuss and interpret the results presented in Chapter 5 (*The schools and the departments and how they used the PD*) and Chapter 6 *(How the PD materials were used by teachers*) from a theoretical perspective.

I addressed the question, '*how do teachers use the professional development materials: what do they attend to and why?*' at two levels: at the level of the department and the influence of the school and external context *and* at the level of the individual teacher.

How the PD was used at a department level

In Chapter 5, I presented results in relation to the *fidelity* with which the PD was used in the three schools that completed the PD programme. I also carried a contextual analysis of the four schools that started the programme. The analysis of fidelity presented a measure of how the PD cohered with the schools' contexts. Context, I considered at three levels: the external context, the school-level context and the department-level context.

Fidelity was used as measure of the degree to which the PD was implemented in a way consistent with the design intentions. The PD materials included guidance on running the PD sessions. There was a presentational tool, the Bowland player, which provided a platform for presenting the video materials which were included in the PD. There were also session plans. The expectation was that the PD sessions could be presented in different ways, but there were fundamental ideas and models of practice that needed to be included. The *fidelity* measure was designed to identify the extent to which there was a discrepancy with the approach suggested in the PD.

The key result was that in two of the schools, Boxton and Norman Fletcher, the fidelity with which the PD was implemented decreased over the four sessions (two modules). At Barrington, fidelity was sustained through the two-module programme. It is important to point out that Hilltown stopped the PD after the first module so the PD sessions were not analysed for fidelity. However, I still consider how contextual factors had an influence on what they did.

I relate the *fidelity* profiles of each school to the idea of *coherence*. According to Desimone et al. (2002), *coherence* is a characteristic of effective PD through "...incorporating experiences that are consistent with teachers' goals [and are] aligned with state standards and assessments..." (p. 83). I took the idea of 'alignment' but considered a more sophisticated conception of the contextual factors which went beyond 'state standards and assessments' posited by Desimone et al. Informed by theory about professional development context (see Cooney and Krainer, 1996; Krainer, 2006; Llinares and Krainer, 2006), I derived a hierarchical coherence/contextual framework which featured, *the external context*, *school-level context* and *department-level context*.

From the analysis of each school's context, which was presented in Chapter 5, I summarised the coherence/contextual characteristics. A summary of the results is shown in Table 8.1. For each school, I consider the relationship between *coherence* and *fidelity*.

Boxton

Boxton had a high *PD coherence* in terms of its external context (see Table 8.1, p. 180). It was getting good examination results and had received

Table 8.1: Summary of PD coherence at different contextual levels and fidelity profile for each school.

	Context level			
School	External	School	Dept	Fidelity
Boxton	high	moderate	moderate	declining
N. Fletcher	moderate	low	low	declining
Barrington	moderate/ low	low	moderate	stable
Hilltown	low	low	low	ceased participation

The possible descriptors for each contextual level are: *high*, *moderate*, *low*.

an 'outstanding' judgement from OfSTED. Case studies have shown that schools in challenging accountability contexts (e.g. in special measures) result in a performativity culture and pressure to normalise practice (Hall and Noyes, 2009; Perryman, 2006, 2009; Perryman et al., 2011). There was no evidence that the school leadership team perceived a need to conform to what they considered to be the kinds of teaching valued by OfSTED. Neither did they have to encourage or enforce a teaching model that was focussed on examination results. However, at the end of the final PD session teachers spent five minutes discussing what OfSTED inspectors valued. At Boxton, performativity pressures were not entirely absent, but they were minimised because they were producing good results.

The school's improvement plan referred explicitly to the, "project with the University of Nottingham" in developing students' independent and collaborative learning. The plan was displayed on the maths office wall, this suggested the PD was integrated into the school's strategy. This, however, was where the integration ended. The school did not allocate resources in order that the mathematics department could dedicate meeting time for PD sessions. Furthermore, the school did not undertake an evaluation of the PD. It has been shown that schools rarely evaluate PD initiatives (Pedder et al., 2008) and this has been recognised as limiting the impact of PD (OfSTED, 2006; Pedder et al., 2008). At Boxton, the extent to which the PD was integrated into the school development plan was that it featured in the development plan documentation.

The departmental culture appeared team-spirited. This suggested the potential for collaboration, this has been identified as an important characteristic of effective PD (Cordingly, Bell, Rundell, and Evans, 2003; Desimone et al., 2002; Stoll et al., 2006). However, the indication was that the Boxton mathematics team worked together cooperatively and liked to achieve consensus. This did not equate to collaboration in which one might expect critical debate as well as cooperation and consensus building.

This analysis revealed that Boxton, compared to the other schools, was in a situation where the PD was most coherent and most aligned to conditions. However, the fidelity with which the PD was implemented declined, indicating that perceived coherence decreased. That is, the department did not treat the second module with same importance as the first.

There are a number of possible reasons why the fidelity declined. An important factor was that Amy ran the PD sessions at lunchtimes, this resulted in reduced fidelity scores in the second round of introductory and follow-up sessions. From observing the first two PD sessions, (*Fostering and managing collaborative work* – introductory and follow-up sessions), it was clear that Amy had thought carefully about what to include in order that the one-hour session could be completed in a maximum of 40 minutes (see Figure 5.2). This was less evident in the second PD module (*Involving pupils in peer and self-assessment*) the fidelity with which the sessions were implemented diminished further. The problems and issues of allowing time for PD is been highlighted in previous research (see, for example Back et al., 2009; Pedder et al., 2008). Although, the school appeared committed to the PD, it was unable to provide resources to ensure enough time was given for PD sessions.

There was also a fatigue effect: the initial enthusiasm for the project and the PD seemed to subside. There was indication that the department was more interested in the first module—developing group-work and discussion. There seemed to be less interest in developing peer and self-assessment in problem solving. In the school and department development plan, there was a stated aim for improving group-work. In interviews with teachers and the head of department, the PD and the suggested lessons were referred to as the 'group-work PD' or 'group-work lessons' and there was evidence in the lessons that the focus for the department was the development of effective group-work over and above problem solving: it may have been that that the module on assessment was not so relevant. Certainly, the case of David and the longitudinal analysis of his teaching in the observed lesson revealed a preoccupation with effective group-work over and above the problem-solving aspects.

Although I considered the external context to have high PD coherence, it is still likely that accountability has an influence on how schools, departments and teachers judge their needs in terms of professional development even though they, like in the case of Boxton, are judged to be outstanding and are getting good results. While research has focussed on schools in special measures or in challenging circumstance (see, for example Perryman, 2006, 2009) it seems likely that normalising forces arising from a surveillance and performativity culture affect 'outstanding' schools also, albeit to a lesser degree. This makes it difficult for schools to sustain the implementation of PD, where the PD may not be aligned with the 'normal' model. I argue that the 'normal' model would be a traditional teacher-centred teaching approach, based on my discussion in Chapter 3.

It is likely then, the PD project was not fully integrated into the school

improvement plan, because it was not central to the school aims of maintaining its position as an outstanding school. It was department-led initiative supported by the school leadership team. Leadership support for the PD was probably based on the notion that it was motivational—something the department were interested in doing, rather than something central to the school's strategic approach to developing teaching and learning.

The effects of the department context and culture were secondary to the external context and school-level factors. The department were prepared to work collectively and the PD was led effectively. The lack of integration of the PD into school development was the main reason why fidelity declined and this was a consequence of the coherence of the PD with external accountability.

Therefore, in order to sustain the implementation of PD—and especially where the PD invites change—it is necessary that the PD initiative is integrated into the school's improvement and development plan and actions, and is reviewed and evaluated at school level. Otherwise, interest dwindles and is supplanted by a focus on accountability concerns. This is also reflected in the case of Norman Fletcher.

Norman Fletcher

Norman Fletcher had moderate external *PD coherence* (see Table 8.1, p. 180). Although the school had been given an 'outstanding' rating and examination results had been above the national average, results fell in the previous year. While the head of department had committed to the project before the previous year's poor results had been published, she was concerned about participating in the project after the summer.

At the beginning of the PD project, the mathematics department was subject to an internal review. This was an internal inspection which included lesson observations and a review of the department's results. The process was similar to an OfSTED inspection. This was evidence of performativity-led surveillance and would likely lead to an attempt to normalise practice as had been the experience in the case study schools investigated by Hall and Noyes (2009) and Perryman (2006, 2009). However, because the school had been judged as 'outstanding' in the previous inspection, its situation was not as perilous as schools going into special measures or requiring improvement.

I concluded that the direction of travel was likely to be toward a focus on teaching in order to maximise examination success in the short term. This would mean focussed, traditional, teacher-centred lessons with an emphasis on fluency in mathematical methods. On balance, it seemed unlikely that there was going to be strategic response that led to teaching to develop deeper understanding or to develop problem-solving skills. Overall then, I summarised this as a 'moderate' external PD coherence context because it was a context which was not entirely amenable to the Bowland PD, at the same time it did not preclude it altogether.

At Norman Fletcher, the PD was less well integrated in to the school improvement plan. Although, there was some relationship between the PD and issues raised about students' independent learning in the previous OfSTED inspection report. There was no evidence of the PD being documented in school or department development plans. It was largely the initiative of the head of department and approved by the headteacher. Certainly, no resources were provided nor was evaluation planned.

In the mathematics department, there was less evidence of a collaborative culture than there was at Boxton. It was a large department of fifteen teachers. It reflected Hargreaves' (2000) characterisation of the *Age of the autonomous professional*. Teachers working individually in classrooms that were effectively private spaces. Furthermore, the head of department's leadership approach was consistent with a traditional hierarchical command and control style. PD sessions led by the head of department featured many lecture-style activities and instructions were given to staff about what aspects of the PD they should do.

Similar to Boxton it was the external and school-level contextual factors that explained the declining fidelity with which the PD was implemented through the project.

This also supports the conclusion I reached about the implementation of the PD at Boxton. In order to sustain implementation the aims of the PD would need to have been more integrated into the school development plan.

The next case appears to contradict this, however the particulars of the case reveal why there was an exception.

Barrington

At Barrington, the situation was a little worse, in terms of external-context and PD coherence. Results had been below the national average for a number of years and an OfSTED inspection was imminent. The head of department believed that if the school was lucky, it would get a 'requires improvement' judgement. It was not clear what the response was going to be by the school leadership team. I saw little evidence of any long-term strategic improvement plan. It was going to be necessary to improve results quite drastically. I expected that at some stage there would be focus on results which would lead to a short-term focus on teacher-centred teaching. Although, at department level, there were, as I come too shortly, many positive contextual factors. However, externally, accountability pressure was imminent and this threatened the coherence of the PD. I therefore judged external PD coherence to be moderate or low.

At Barrington, like Norman Fletcher, involvement in the PD project was a department-led initiative and was not integrated into school-level improvement plans.

What Deborah the head of mathematics at Barrington had effectively done was define her own strategic aims for the department. She had carried

out her plan, which was to implement the PD with the whole department, but aimed the PD more at her committed core group. As a result she was able to sustain her personal commitment to the PD. Consequently, as a result of her strategic autonomy, the fidelity of the PD sessions was sustained, but the level of participation in the department was lower than in the other two schools.

In spite of a difficult external and school-level context, the energy and commitment of the head of department contributed to sustaining the implementation of the PD in a way that was consistent with its aims. In addition, she was shrewd in focussing the PD on a particular group of interested teachers, although all of the department were required to attend the sessions.

In this case, it was evident that strong and experienced department leadership can overcome the effects of the external and school-level context. Yet, even though Deborah sustained the implementation of the PD, in spite of school-level ambivalence, it was really only part of the department that were fully involved. I suggest, therefore, that what happened at Barrington was consistent with the conclusions reached about the effects of accountability and school-level integration in the previous two cases. The difference was that the strength of department leadership did remediate the situation to some extent.

The final case is an extreme example of the effects of accountability and performativity on the implementation of the PD.

Hilltown

Hilltown—in terms of its external accountability context—was at the other extreme to Boxton. Shortly after the project started the school was inspected and judged to 'require improvement'. The head of department resigned, as did the teacher who had volunteered to lead the PD. I returned to the school and interviewed a teacher after the project and he explained that he thought the resignations were linked to and caused by repeated lesson observations carried out by the school leadership team. This was consistent with the conditions observed by Hall and Noyes (2009) in their case study, where teachers were under pressure to be observed frequently, conform, and experienced significant levels of stress as a result.

I interviewed a member of the school leadership team to elicit reasons why the school was not able or not willing to pursue the PD project. He explained that although he believed the PD was worthwhile and important, the school's resources needed to go into improving on their OfSTED grading. This meant that the PD they wanted was of the type that helped teachers present lessons that were going to be judged 'good' or 'outstanding' by OfSTED. This was similar to Perryman's (2006, 2009) analysis of the leadership in case studies schools in special measures. They implemented a surveillance culture to monitor teaching and encouraged particular teaching models (Perryman et al., 2011). The Bowland PD was not aligned to this

aim. I therefore considered Hilltown to have low external PD coherence. This was borne out as it withdrew from the project.

Therefore, this case is consistent with my analysis of the three preceding cases. Accountability in the external context leads to performativity and normalisation of teaching, a consequence is that the PD was not integrated into school-level strategy. In this particular case, not only was it not integrated, it was overtly excluded by the school leadership.

To summarise and synthesise the analysis of the way the four schools implemented the PD, and the effects of contextual factors, I draw on my discussion of professional learning from a *social learning theory* perspective in Chapter 3 (Section 3.3, p. 49). My discussion here concludes with a picture of the normalisation of teaching and a performativity culture as a result of accountability. The more pressure a school is under, the greater the pressure to normalise teaching. Normalisation is toward traditional teacher-centred teaching. This is consistent with my theoretical analysis in Chapter 3 and the idea of the ubiquity of teacher-centred teaching.

My analysis in this section can be further explained using *social learning theory*. *Social learning theory* tells us that in order for individuals to behave in ways other than the norm; they require models of alternatives and self-efficacy in those alternative approaches. For teachers implementing new approaches, they need opportunity to see and imagine the new approach, and the confidence that it will work in their classroom. One influence on self-efficacy is the *physiological and affective* state of the individual. If we are tired, ill or stressed then our self-efficacy will be reduced. Therefore, in a high-stakes accountability culture, which features surveillance through repeated observation, and pressure to improve examination results, it is highly likely that teachers experience levels of stress that do not support their self-efficacy in alternative teaching approaches. I develop this further through the remainder of the discussion in this chapter.

This is exacerbated when the valued models of teaching are oriented towards short-term improvement in examination results: where the emphasis is on teaching for proficiency in particular methods, and approaches that maximise students' performance in examinations. This is consistent with a traditional teacher-centred approach which focuses on demonstrating methods and student practice.

From a self-efficacy perspective, and from a consideration of the valued models of teaching, the effects of accountability can be explained. At school level then, where leaders are accountable for results and performance, the pressure to perform is likely to have an impact on the culture of the school and consequently on teacher self-efficacy, as well as what is tacitly or even overtly proffered as the valued model of teaching.

At Boxton, the pressures were less than at the three other schools. However, the kind of teaching that was promoted in the PD appeared not fully consistent with the school's aims. The tacitly valued approach would be predominantly toward maximising school results. Therefore—and this was evident in the extent to which the PD was integrated at school level—

the models proposed in the PD were only marginally valued by the school. This explains why the department was not given resources in order to sustain the PD's implementation. The department began enthusiastically but interest diminished because it was not fully supported by the school. This is consistent with the experiences at Norman Fletcher and Hilltown. Barrington was the exception through the efforts of the head of department and that she effectively worked with only part of the department.

Overall, *context* has previously been found to have an impact on the effectiveness of PD (Desimone et al., 2002) but is rarely considered (Rösken, 2011). In this study, I have shown how the effects of context impact on the implementation of the PD. Contextual factors can have such negative effects on PD implementation. In spite of this, the PD had an effect on teachers' self-efficacy and practices, as I will discuss later in this chapter where I consider the nature and extent with which the PD had an impact. This leads on to developing an overall understanding of how this kind of PD might be improved and also understanding more about professional learning processes.

In the next section, I discuss how individual teachers used the PD and look at professional learning processes in more detail.

Teachers' attention in part of a PD session

This discussion relates to the results in Chapter 6 (Section 6.1, p. 128), where I presented the analysis of teachers' discussions in part of a PD session, with the aim of identifying what teachers attended to and noticed about the PD.

My analysis revealed four pedagogical aspects that teachers 'noticed' and attended to in the PD. These were as follows:

1. **Allowing students time to discuss an open-ended problem**

   In the video, the teacher, Eve, had asked students to think about and then discuss, 'how many teachers are there in the UK?' They were given one piece of information, that the UK population was about 60 million. Students were asked to discuss their assumptions, reasoning and solutions. Nigel and Amy expressed concern about the divergent ideas and approaches students come up with. They were 'off task' and had unproductive or unpromising approaches. Nigel thought the teacher should have intervened in order that the students had a more efficient way of getting a solution.

2. **The lesson structure**

   Mary and Jane observed the underlying lesson structure: allowing students to work alone, then working and discussing in pairs and finally in groups of four—a *think-pair-share* structure. Jane noticed the *think-pair-share* structure.

3. **The use of the resources**

   Phil commented how he liked the use of small whiteboards. In the video, students were using them to try out calculations—it gave them freedom to try an idea, rub it out and try something else. They were not bound to finding a particular approach or method.

4. **The use of questioning to elicit and promote reasoning**

   Tony noticed how Eve used the question 'why?' as a means to encourage students to think about their assumptions and reasoning.

It is difficult to establish why these aspects of the example lesson were more prominent and worthy of comment and discussion. The fact was that these aspects moved teachers to make comments. What were important were the comments teachers made about these aspects of the example lesson.

The comments teachers made were evaluative, they expressed positive and negative opinions about the elements of practice they observed. For example, Nigel was critical about allowing students the freedom to discuss a range of different assumptions and methods. He said that the teacher should have intervened to prevent unfruitful lines of inquiry. While Tony was positive about the use of questioning.

The basis for the evaluations teachers made about these aspects of the example video provides insight into how teachers engaged with the PD materials. Furthermore, it reveals something about the professional learning processes.

It is the nature of the criteria the teachers used for their evaluations that is central to my analysis of the teachers' discussion and in explaining what teachers attended to and noticed.

There are three possible explanations for their assessment. The first is that teachers evaluated what they observed based on a forward-oriented judgement of the extent to which they would be successful if they implemented what they observed. This is based on *social learning theory*.

The second is that it is a judgement made using more general preferences about what teachers view to be effective teaching, without the forward orientation. This is consistent with the idea of teachers' beliefs about teaching and learning (Ernest, 1989; Fenstermacher, 1978; Pajares, 1992; Thompson, 1984), where teachers value general perspectives on teaching and learning.

The third explanation is that it is an intuitive, in-the-moment response to what they observed: a random response to the observation. Since this is a professional setting, I rule out the contribution of this explanation.

The most likely explanation is the first one, that the evaluation is forward-oriented and related to teachers' existing mental models of teaching, practice and pedagogy. This I argued, when I presented the results in Chapter 6 (Section 6.1, p. 134). Given the context—the PD session precedes a lesson in which teachers are going to try out the ideas—they

are making assessments about whether the suggested approach will work for them. Therefore, forward-orientated judgement and evaluation are the most likely explanation for the comments.

They were watching the video example in order to plan their lesson and to identify pedagogical approaches they could use in the lesson. My analysis of the discussion the teachers had about the video supports this assumption: there were examples of expectancy-based functional evaluations. For example Nigel's negative evaluation of the use of discussion without teacher direction, Phil's positive evaluation of the use of small whiteboards, Tony's positive evaluation of the use of questioning and Jane's observation of the lesson structure. Each can be considered to be saying either "I could do this" or "I couldn't do this."

The process the teachers were engaged in was to observe an example lesson, in a video, with the expectation that they would implement the suggested approach in a lesson, as part of the *into-the-classroom* phase of the PD. They would try out the approach they observed, adapting it to their preferred style. There is a further expectation that they would use the approach in their day-to-day teaching.

I do not rule out the rôle of teachers' more general preferences or 'beliefs'. Indeed, preferences and values are likely to come into play. However, the complexity of teaching requires that teachers think very carefully about how they make changes to what they are doing. I discussed, at length, why teacher-centred teaching tends to be prevalent in Chapter 3. Teachers develop routines that are they find to be effective (Cuban, 1993; Leinhardt, 1988; Stigler and Hiebert, 1999). Teaching is based on "... a highly efficient collection of heuristics that exist for the solution of specific problems in teaching" (Leinhardt, 1988, p. 146).

The discussion between the teachers, having watched the video example of the lesson based on the approach used in the PD, gives a visible presentation of *observational learning*. This (as I explained in Chapter 3) involves observing others' behaviours, modifying and retaining what was observed and using the mental model to guide future behaviour. As Bandura explained it:

> [F]rom observing others[,] one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action (Bandura, 1977, p. 22).

It is a multiprocess phenomenon, consisting of four sub-processes: *attention*, *retention*, *production* and *motivation* (Bandura, 1986, p. 52). These are illustrated in Figure 8.1.

Individuals do not learn through observation unless they "... attend to and perceive accurately, the significant features of the modelled behavior" (Bandura, 1977, p. 24), i.e. *attentional processes*. *Retentional processes* concern the conversion of observations to mental models and symbolic representations. The *production process* involves the conversion of the sym-

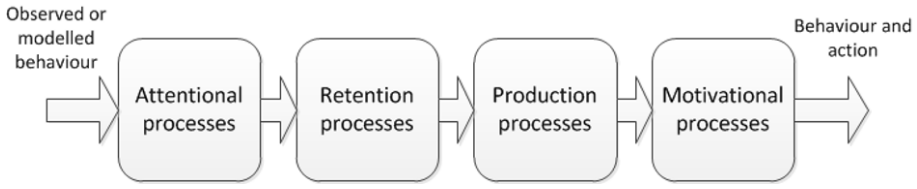


Figure 8.1: Observational learning sub-processes.

bolic codification of observed behaviours into action and finally the *motivation processes* address how, out of the numerous behaviours observed and symbolically retained, certain behaviours are constructed and enacted.

What teachers discussed about the pedagogic elements they observed was a manifestation of the *attentional processes* of observational learning. The *attentional processes* of observational learning are dependent on the characteristics of the modelled events (the behaviour that is being observed) and on observer attributes (Bandura, 1986).

The observer attributes in attentional processes of observational learning are: *perceptual capabilities*, *perceptual set*, *cognitive capabilities*, *arousal level* and *acquired preferences* (Bandura, 1986, p. 52). The observer, in order to observe behaviours, must therefore have the appropriate cognitive and sensory powers in order to observe behaviours (*perceptual capabilities*) at the same time predispositions must not place the observed behaviour outside of sensory perception (*perceptual set*). At a cognitive level, the observer must have the appropriate capabilities and at an affective level, they must have appropriate levels of arousal.

In this context, I concluded that the teachers all demonstrate the required characteristics in order to effectively attend to the modelled behaviour. I therefore focussed on the model attributes.

There are six attributes relating to the modelled event: *salience*, *affective valency*, *complexity*, *prevalence*, *accessibility* and *functional value* (Bandura, 1986, p. 52). The observed behaviour has certain noticeable aspects that must stand out (*salience*) or have some form of emotional significance (*affective valency*). Observed behaviours must also have the appropriate degree of *complexity*—complex enough to be interesting and have value, but not too complex as to be inaccessible. The idea of *prevalence* suggests that that observed behaviour has some degree of authority. Finally, the observed behaviour must appear to have use: it must have *functional value* (Bandura, 1977, 1986). I consider each of these in turn.

Salience This is an aspect of the modelled behaviour that is prominent. The things that teachers noticed: *allowing students time to discuss an open-ended problem*; *the lesson structure*; *the use of the resources* and *the use of questioning to elicit and promote reasoning* were all therefore salient. What made them salient is difficult to establish. However, looking at the other model attributes gives some indication.

Affective valency Nigel's concern about divergent discussion was visible through the discussion and this suggested he had strong feelings about this. It is probable that issue has *affective valency* for him. He might have had a stressful experience where students did not know what to do in a lesson and he felt a loss of control.

Complexity The modelled behaviour must not be too complex to be inaccessible to the observer. Here teachers are noticing elements of a complex set of behaviours, a lesson to support students in developing problem-solving skills. Teachers notice elements as evidenced by their discussion. This indicates they broke down the 'complex whole' into components thus reducing the complexity.

Prevalence This relates to the authority of the modelled behaviour. It is related to the effectiveness characteristic of PD leadership identified in Chapter 2. It is a global characteristic of the materials, and the context that they are implemented, that they have authority and therefore *prevalence*.

Accessibility Given the design of the materials and the context of their implementation, this was a further global characteristic of the modelled behaviour. In the discussion between the teachers I observed the model was evidently accessible. Although it cannot always be assumed and needs to be considered by designers and developers.

Functional value This was one of the most important attributes of the modelled behaviour. One in which I discussed at length earlier. The PD materials offer a practical model for teachers to implement in their classrooms. The materials were designed to have *functional value*.

This analysis is summarised in Table 8.2. It shows each of the four aspects noticed by teachers in the PD. Each of these had a specific model attribute: *affective valency* or *functional value*. All aspects noticed were assumed to have an aspect of *salience*, *complexity*, *prevalence* and *accessibility*.

This theoretical analysis of the results supports the assumption that teachers were watching the video and considering what they observed from a functional perspective.

Observational learning provides a means by which mathematics teachers' professional learning can be explained. This analysis of a relatively brief discussion between teachers about an example lesson, showing the suggested ideas, provides a window into how teachers use the materials more generally, as a source of ideas and models that they can use in their classroom.

The key conclusion is that, what teachers observe, what they notice and attend to, is related to what aspects they consider they will or will not have success with. This is related to the attentional processes of observational

Table 8.2: Aspects of the PD attended to and their observational learning model attributes.

Aspect of modelled behaviour noticed in the video example	Model attributes	Global model attributes
1. Allowing students time to discuss an open-ended problem	*Affective valency*	
2. The lesson structure	*Functional value*	*Salience, complexity,*
3. The use of the resources	*Functional value*	*prevalence, & accessibility*
4. The use of questioning to elicit and promote reasoning	*Functional value*	

learning and provides an explanation of what teachers might attend to and notice. It is necessary, to consider the other aspects of the observational learning processes *retention*, *production* and *motivation* (see Figure 8.1, p. 189). However, in this study I do not look at retention processes, but the production and motivational processes. What aspects of the models do teachers use in lessons and what are their motivations for this? This I discuss in the next section.

How teachers implemented the ideas suggested in the PD in lessons.

In this section, I discuss the results presented in Chapter 6 (Section 6.2, p. 140). This was an explanatory case study of three teachers and how they implemented the ideas suggested in the preceding PD session. This also follows on from the analysis in the previous section, where I looked at what teachers attended to and noticed in the PD. The explanation was based on the sub-processes of observational learning, in particular the attentional processes. This showed a link, in this context, between noticing and what teachers attended to, with expectancy evaluations and an evaluation of the functional value of aspects of the modelled lesson. In other words, they observed a lesson (as a video) with a thought to how it would work for them.

In this section, I look at how the observed models translate into the classroom. For these case studies the teachers were: Imran (Barrington), David (Boxton) and Cath (Norman Fletcher).

Imran and David had been teachers for eight years. Cath was a new teacher. Imran and David drew on their experience in planning and implementing the lesson and made adaptations. While Cath implemented the suggested lesson plan included in the PD materials. It was evident that teaching and classroom experience influenced the way in which the teachers used the PD.

This is consistent with my analysis of the discussion between teachers in the PD session in the previous section. Teachers' assessment of what they observed was drawn from classroom experience and their sophisticated mental models of what they thought worked, or indeed, did not work. They were observing the lesson and saying something along the lines of, "that would work for me", "that wouldn't", or "I think I could do this". These were attentional processes based on functional value, expectancy and functional potential.

This part of the study extended this further, I considered *how* teachers implemented the ideas taking a model and then producing action. The 'model' represents the ideas suggested in the PD, in handouts, in lesson plans and in the video examples of the lessons. Teachers attend to aspects of the *model* using *attentional processes* (Bandura, 1986, p. 52). Those models are retained as codified, symbolic mental models (*retentional processes*). Teachers then act using the models to guide their actions and behaviour (*production processes*), the selection and implementation of mental models is based on *motivational processes* (Bandura, 1986, p. 52).

In the analysis of Imran, David and Cath's actions, in the observed lessons, I was concerned with the *motivational processes*: why had they implemented the suggested approach in the way they did? What were their motivations in relation to the observed model and implementing it in the *into-the-classroom* lesson?

Imran made most adaptations to the observed model. He had used the lesson structure—taking the ideas from the lesson plan—and planned a lesson for his year 11 set 1 class. This lesson included two cycles of the suggested plan in a single lesson, each with a distinct problem. He explained that he did this because the problems were too straightforward for his high-attaining class. He said that when he planned the lesson, that he thought the class would get to the answer too quickly and so he thought he would use two problems with the class and use the lesson plan as the basis for the structure of each part of the lesson.

The result of Imran's decision was that the lesson did not give students chance to grapple with a challenging problem. The two problems were of insufficient demand so they became more straightforward and more routine. As a result, the lesson became more traditional and teacher-centred. The difference was that Imran had not started the lesson with an explanation or demonstration of a method. It was a traditional teacher-centred lesson but without an initial teacher exposition on methods to use.

Why did Imran chose to adapt the ideas in this way? Was it a genuinely practical solution to implementing the model, with the tasks available and with a high-attaining group? Or did he not feel confident in allowing students the chance to work on, discuss and collaborate on a non-routine problem? The answer is most likely a combination of the two.

However, scratching at the surface revealed more, and indeed, evidence that Imran preferred to keep the lesson more teacher-centred. He spoke of his own confidence in the approach suggested in the PD and how he did not

feel confident in it, but said he was willing to try things. This was also supported by the observations made by the head of mathematics at Barrington who explained Imran's strong preference for traditional teaching. It is my conclusion that Imran adapted the lesson to make it less student-centred and more teacher-centred.

The explanation for what I observed in Imran's *into-the-classroom* lesson is also supported by previous research into the implementation of reform-oriented ideas. Cuban (2009), in a development of his previous historical analysis of pedagogy (Cuban, 1993), identified a condition of *teacher-centred progressivism*. This hybrid pedagogy is principally teacher-centred but with features of student-centred teaching, for example, the class might be organised for group-work but the lesson might have a teacher-centred orientation i.e. the teacher demonstrates a method or idea and then students practice using largely routine questions.

Cuban (1993) argued that teacher-centred progressivism was a feature of contemporary classrooms in the US. He explained that the demands of teaching (I discussed this in Chapter 3) in state-funded secondary schools resulted in the use of teacher-centred practices because of their historical reliability and they afforded the teacher an economy of effort. The pressure of reform resulted in, according to Cuban (1993), the adoption of the surface features of reform.

Cohen's classic single case study of Mrs Oublier illustrates the phenomena of teacher-centred progressivism. Mrs Oublier claimed to have transformed her teaching as a result of participating in reform-oriented PD. What Cohen (1990) observed was limited substantive student-centred teaching. Mrs Oublier had adopted an approach similar to Cuban's teacher-centred progressivist approach, which was traditional but had some surface student-centred aspects.

What I observed in Imran's lesson was an example of teacher-centred progressivism. I can go further by positing a theoretical explanation for this phenomenon. From a *social learning theory* perspective self-efficacy beliefs influence the choice of behaviour and as a consequence influence the way in which models are interpreted and enacted (Bandura, 1997, p. 160). According to Bandura, "self-efficacy refers to beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). Imran's inefficacy influenced the way in which he reproduced the observed models and adapted them to a form that he was more comfortable with. This is consistent with research that has suggested that efficacious teachers are more likely to innovate and experiment (Berman and McLaughlin, 1978; Guskey, 1988; Stein and Wang, 1988).

I am mindful that—as I was when I presented the results in Section 6.2 (p. 140)—my interpretation of Imran's teaching might be considered disparaging. However, I consider Imran's case to be important and significant in understanding how reform-oriented professional learning does and does not work. Previous research (Berman and McLaughlin, 1978; Cohen,

1990; Cuban, 2009; Guskey, 1988; Stein and Wang, 1988) suggests that for many teachers the characteristic that acts a barrier to implementing a wider range of teaching approaches is one of self-efficacy in the suggested approach. More so than teachers' more general perspectives, orientations or 'beliefs' about teaching: it is their belief in their ability to successfully implement the models suggested that is more the important characteristic. Imran, I believe, is representative of many teachers' struggles in this respect. This single case is highly valuable in illuminating theory as well as in considering what might be done to improve the effectiveness of PD.

Abrami et al. (2004), which I discussed in Chapter 3, studied the implementation of cooperative learning in primary and secondary schools in Canada. They investigated teachers' motivation to implement cooperative learning ($n = 754$). The model for motivation for implementation was based on three components: (1) how highly s/he values the strategy; (2) how successful s/he expects to be; and (3) how high s/he perceives the costs of implementation to be (p. 203). Their data used teacher self-reports and relied on the openness of respondents. However, they found that *expectancy*, i.e. how successful teachers' believed they would be in implementing the approach was the most important motivational component. Their composite model derived from regression analysis was as follows and shows the relative importance of *expectancy*.

$$(0.44 \times \text{expectancy}) + (0.04 \times \text{value}) - (0.01 \times \text{cost}) = \text{use of cooperative learning}$$

Abrami et al. (2004, p. 211)

While Abrami et al. (2004) provided strong evidence that implementation is related to expectancy motivation and supports the importance of teaching self-efficacy in relation to the reform, they do not account for the way in which teachers adapt and alter the proposed approaches. This supports the importance of using a multi-component conceptualisation such as *social learning theory*, with observational learning, concerned with modelled behaviour, adaptation of the models and implementation, and self-efficacy, reflecting individual beliefs about capability.

David provided an important contrasting case. He was more efficacious in the suggested approach and was willing to implement the ideas in the *into-the-classroom* phase. There were no major adaptations, he used the structure and ideas proposed in the preceding PD session. However, there were subtle, but no less important implementations that David included. These were entirely consistent with the discussion above.

David focussed on developing the organisation of group-work and this, as I commented in the results chapter, seemed to be a greater priority than developing problem solving itself. Although, problem solving, in David's lesson, was not entirely neglected. However, David had taken part of the overall approach suggested in the PD and focussed on something that

he found manageable and relatively 'easy'. David, I would argue was a more efficacious teacher than Imran, yet he seemed to want to supplement a traditional teacher-centred approach rather than engage fully with student-centred approaches. While David was observably more comfortable than Imran with a student-centred approach in the lessons observed, he did repeatedly express concerns about fitting problem solving into to the curriculum where attention has to be paid to preparing students for examinations. Overall, I suggest similarities between Imran and David in a propensity to 'tone-down' reform and implement a teacher-centred progressivist approach.

Cath's approach contrasted with the way in which David and Imran adopted practices from the PD. Cath appeared to take the suggested student-centred problem-solving approach as a 'whole package'. Although she found student behaviour more challenging with the class observed, she appeared more willing to embrace the whole approach. This was a result of her relative inexperience. Cath, since she was new to teaching, did not have an established practice or approach and as a result she appeared less concerned with trying to find a way of fitting in the suggested approaches with her existing approach.

In sum, teachers made adaptations to the suggested approach based on their teaching self-efficacy. They made judgements about the extent to which they would be successful with the suggested approach in their classroom. That judgement was based on their teaching experience. New teachers would be more likely to implement the suggested approaches without adaptation since they do not have previous experiences to judge what will or will not be effective.

This can be explained further by considering the observational learning sub-processes, the motivation and production sub-processes (see Figure 8.1, p. 189). Teachers act using mental models, acquired through observational learning, to guide their actions and behaviour (*production processes*), the selection and implementation of mental models is based on *motivational processes* (Bandura, 1986, p. 52).

This analysis was concerned with implementing the ideas in an *into-the-classroom* lesson. In the next section, I consider the impact of the PD more generally, by looking at the changes in teachers' practices and self-efficacy beliefs.

8.2 Changes and effects

In this section, I discuss the results presented in Chapter 7 relating to the mixed-methods analysis of changes in teachers' beliefs and practices. I also consider what teachers found more or less difficult to implement and how practices changed.

8.2.1 Changes in teaching self-efficacy

For all teachers, who were involved in the PD in the three schools and that completed two PD modules ($n = 18$), teachers' self-efficacy changed in one factor of the standard teaching self-efficacy instrument. The factor that changed was *efficacy for instructional practices*. This was with a small to medium effect size. Teachers' *teaching problem solving self-efficacy* also increased significantly with a medium to large effect size.

Since there was no control group or no random assignment of the professional development, it was not possible to attribute an effect and causality to the PD through this quantitative analysis alone. Furthermore, while the standard teaching efficacy instrument (Tschannen-Moran and Woolfolk Hoy, 2001) had been subject to validation tests in previous studies, the self-efficacy for teaching problem-solving questionnaire had been developed for this study. Although, this proved to be highly sensitive—judging by the effect size. However, it requires further validation with larger samples to ensure the validity of the underlying factor or factors that are being measured. Overall, the qualitative analysis of teachers' self-efficacy changes support the claim that the PD had an impact on teachers' self-efficacy and, indeed, their self-efficacy in teaching the approach suggested in the PD.

My interpretation of this combined result is that teachers became more confident in teaching using the approaches suggested in the PD. In spite of the limitations described in the previous paragraph, this result has plausibility based on an elementary consideration of the situation: teachers had been exposed to alternative models and structures for lessons and alternative pedagogical approaches. They had opportunity to think about and try the ideas out and, in general, teachers, although concerned about student behaviour, were supportive of the approach.

A development in confidence as a result of taking part in PD is not a particularly ground-breaking result. However, this analysis goes beyond simply revealing that teachers developed more confidence. It shows that teachers became more self-efficacious in the suggested approach. In Chapter 3, I drew on the distinction made by Bandura, between *confidence* and *self-efficacy*. Confidence refers to the strength of a self-referent belief; in contrast, self-efficacy is a forward-oriented self-referent belief in a particular activity or in complex structure of related tasks and activities. According to Bandura (1997), a self-efficacy assessment, "... includes both an affirmation of capability level and the strength of that belief" (p. 382).

Self-efficacy is a more precise theoretical term than 'confidence'. More importantly studies by Bandura (1997) have shown that self-efficacy not only reflects affective aspects, such as confidence and motivation, but also underlying knowledge and skill. In the results in Chapter 7, teachers characterized their dispositional relationship with the PD as in being in terms of 'confidence', since this was a forward-oriented and self-referent assessment about their beliefs in their ability to implement the ideas suggested in the PD, what they refer to as confidence is an assessment of self-efficacy.

This was reflected in the comments of two of the heads of departments.

Two of three heads of departments explained the effects of the PD in terms of developing teachers' confidence in the approach suggested in the PD. While teachers did not characterize their learning in terms of self-efficacy, they highlighted the need for confidence in the suggested approach. Although they did not refer to changes in their confidence or self-efficacy, they did not describe their learning in terms of any particular cognitive or affective component. This is because I did not ask teachers directly about changes in their thinking except in terms of the changes in their perspectives about teaching and learning mathematics. This was a conscious decision not to compel teachers to categorise their own professional learning, rather to explore explanations through the research.

So, I concede that the characterization of professional learning, from the perspective of heads of departments and teachers, was in terms of developing self-efficacy in the suggested approach, but rather weakly so. On the other hand, no participant provided a prominent or detailed account of their professional learning. So although there was a 'language of self-efficacy' used by heads of departments and teachers, it was, as I have suggested the only way in which teacher learning processes were characterized by participants. I therefore argue it supports my thesis of a change in self-efficacy that is attributable to the PD.

My conclusion then: based on teachers' responses relating to having the confidence to teach using the suggested approach; taking account of the two of three heads of departments' observations: and the results of the questionnaire—that the changes in self-efficacy were attributable to the PD—teachers overall, became more confident in, knowledgeable about and skilful in using the student-centred problem-solving approach modelled in the PD as a result of participating in the PD.

My main consideration here, as it has been though this discussion chapter, is the processes rather than effects. I therefore consider how efficacy may have developed from a theoretical perspective and in so doing account for observations I made about individual teachers.

In Chapter 3 (Section 3.2.3, p. 43), I considered the sources of self-efficacy. The four sources of self-efficacy are *enactive mastery experience*, *vicarious experience*, *verbal persuasion* and *physiological and affective states*. Bandura (1997) proposed that the main source of efficacy beliefs is through mastery experiences. Efficacy can also be developed vicariously, by observing others. Seeing a colleague or someone we relate to demonstrate success in an activity can contribute to our self-efficacy in that activity. Verbal persuasion is a weaker source of self-efficacy, this is where individuals can be persuaded that they will be successful. Finally, physiological and affective states influence efficacy, if a person is suffering from ill-health, stress or fatigue, for example, their self-efficacy can be undermined.

All of these can be used to explain the growth in self-efficacy in teaching problem solving. Teachers had opportunity to develop self-efficacy in the *into-the-classroom* lesson. Although, in some cases these experiences were

not positive and did not necessarily provide enactive mastery experience. I refer to, for example, Pete and John at Norman Fletcher (see Section 7.1, p. 158), where their perceived experience of student behaviour resulted in them having negative experiences in observed lessons. On the hand, Barry (Barrington) and Adrian (Boxton) had positive experiences in the *into-the-classroom* lessons and this could have contributed to developing efficacy in the approach. Of the other teachers, the experiences of trying to teach problem-solving lessons were reasonably positive and therefore I assume that is the reason why teachers, overall, had a positive change in self-efficacy over the course of the project. It is reasonable that experience of teaching the suggested approach is going to contribute to increased confidence in that approach. Except, of course, where the experience teachers had was negative.

There was also opportunity to develop self-efficacy in teaching problem solving vicariously. The video examples of the approach that were used in the PD sessions could have contributed to teachers' self-efficacy. Imran, for example, attributed some of his confidence to watching the video examples.

Verbal persuasion was also likely to have been important; those who led the PD and department colleagues were generally encouraging and supportive of each other in PD sessions. This would have offered a source of self-efficacy in order that teachers had the confidence to try the ideas out, in the first instance at least.

It was not possible to determine the relative weights of the different sources of efficacy. However, Tschannen-Moran and McMaster (2009), in their study of elementary teachers participating in PD in the US, examined the relative strengths of sources of self-efficacy in PD. They found that an "authentic task-specific mastery experience" and "individualized verbal persuasion" (Tschannen-Moran and McMaster, 2009, p. 242) were important in raising efficacy to support the implementation of a new approach. This study suggests that the strongest source of efficacy was through mastery experience, as a result of the *into-the-classroom* phase of the PD.

From this, I concluded that the professional development had an impact on teachers' self-efficacy in the approaches suggested. This, as I proposed in Chapter 3, is an important component in the mechanism of change in PD. I argued, from the analysis of prior research and from *social learning theory* that if professional development is to instigate and sustain change in practice, then the PD must provide the means by which teachers can observe models of alternative approaches and that they must have self-efficacy in the suggested pedagogical models. Professional development must provide the means to develop self-efficacy.

In the next section, I look at, and explain, how teachers' practices changed. However, first I want review the discussion and argument presented so far in this chapter. Thus far, I have shown how the PD was used and implemented and how teachers engaged with and implemented the ideas in their classrooms. In this section, I have shown and explained the effects of the PD on teachers' self-efficacy. In terms of the overall

argument—earlier in this chapter, I considered how departments used the PD materials and how accountability and a lack of integration into school-level development and improvement plans had an impact on the quality with which the PD was implemented. I then considered how teachers' used the materials, how *observational learning* could be used to explain what aspects of the modelled approach teachers noticed and from this, the way in which they adapted or developed the suggested model dependent on their experience and self-efficacy in the suggested approach. Having looked at the way in which modelling and observational learning accounted for the professional learning process, in this section I considered how the PD impacted on teachers' self-efficacy in teaching the model presented in the PD.

Overall, while the accountability culture and lack of school level integration had an impact on sustaining the quality of the implementation of the PD, teachers were able to try out the suggested approach as part of the PD and this was the most likely source in developing teachers' self-efficacy in teaching that approach. Although, teachers were likely to adapt the observed model to a form resemblant of traditional teacher-centred approaches. Yet, teachers developed self-efficacy in the teaching of problem solving. In other words, they were more confident in pedagogies that fostered the development of students' problem-solving skills. Of course, there were exceptions but this is an overall assessment based on the eight observed teachers and the survey study.

My final consideration, in the next section, is how this translated to practice: what was the effect on teachers' practices; how can the effects be understood from the perspective of professional learning and how can they be theorised? And, how do these results relate and contribute to the conclusions proffered so far?

Before moving on to this, I want to consider another aspect of teachers' perspectives and that is teachers' beliefs. The following discussion is important since I am addressing the possibility of an alternative explanation for the effects of the PD on teacher thinking. So far, I have concluded that the effect of the PD was to develop teacher self-efficacy in the suggested approach, I want to consider teacher beliefs as an alternative or complementary explanation. This is also an assessment of underlying theory within the PD design. That teachers' beliefs about teaching and learning mathematics would be influenced through a successful engagement with the PD.

Changes in teachers' beliefs

None of the teachers described changes in their beliefs and this was also supported by heads of departments. In other words, teachers' beliefs about teaching and learning mathematics did not change. They did not, as was hypothesised by the designer (see Swan, 2006a), experience a change in beliefs: from, for example, beliefs aligned with traditional teacher-centred teaching to more student-centred beliefs. In my research all teachers, at the

beginning of the project, were appreciative of the student-centred problem-solving approach suggested in the PD. No one expressed fundamental beliefs that the approach was not valid, not appropriate or not effective. They were asked directly how their perspectives had changed as a result of taking part in the PD and no teacher professed to have experienced a change 'belief'. It is important to explain this since there is a body of research for which teacher beliefs have been at the heart of the theorisation of professional development.

In this research, the emphasis was not on teacher beliefs and, as a result, teachers were not likely to have felt confronted or challenged about the way they taught generally. I did not assume that the way teachers taught was entirely explicable in terms of their beliefs about teaching and learning. Therefore, their explanations for their approach to teaching were richer and in terms of the practical challenges of classroom management, behaviour management and student engagement, rather than driven by an underlying orientation, perspective or belief. I am not entirely ruling out the effects of teacher beliefs, but there were more practical, social and contextual factors that teachers explained influenced the way they taught. This was the observation of Ernest (1989) in his theoretical analysis and by Thompson (1984) empirically. Much subsequent research into teacher beliefs has also highlighted the mediating and moderating function of the social and contextual setting between beliefs and practice.

I suggest that if I had formulated this research with teacher beliefs as a focus, then it would have precipitated or compelled teachers to express a particular belief. The approach I have taken has allowed me to go deeper into the underlying professional perspective of individual teachers.

To exemplify this, one teacher, Pete, did become more negative about the suggested approaches. From this, I could have concluded that his beliefs had become more teacher-centred or traditional. This apparent change in belief was a result of the difficult experiences he had with some students in the lessons I observed. He therefore espoused increasing reluctance in using a more student-centred approach as suggested in the PD—his self-efficacy in the suggested approach had declined. His espoused reluctance could have been interpreted as a belief—a resistance. However, from *social learning theory*, we get a more detailed account of resistance: resistance in terms of affect, such as confidence and motivation. Moreover, this approach offers a theoretically informed means by which teachers like Pete might be supported.

I move on to changes in teachers' practices in the next section and make connections between changes in practice, teacher self-efficacy and in the way departments and teachers implemented the professional development.

8.2.2 Changes in teachers' practices

From the analysis of teachers who attended the PD in the three schools that completed the two PD modules ($n = 18$), self-reports of practice showed

that their teaching had become significantly more student-centred with a small to medium effect size.

This relied on teachers' self-reports, and like the self-efficacy study, there was no control group or random assignment of PD. On their own these results are not sufficient to support the view that the changes were a result of the PD. I therefore considered the analysis of the qualitative data from interviews with teachers, PD leaders and heads of departments. I also considered the observed lessons of the three case study teachers: Imran, David and Cath. Overall, and based on this evidence, teaching had become more student-centred.

Of the case study teachers, Barry and Imran from Barrington, Adrian, David and Christine from Barrington, all indicated that their teaching had changed as a result of taking part in the PD. The Barrington teachers suggested that overall they were allowing students more time to struggle with a problem. At Boxton, teachers suggested that they were more effective in organising group-work. The head of department at Barrington suggested that the school leadership team had reported differences in teaching approaches when the department was observed. At Boxton, the head of department claimed that there was more collaborative student work in the department. At Norman Fletcher, because the head of department did not have access to lessons, they could make no claims about changes in practice.

What I concentrate on in this discussion is the nature and extent of the change in practice.

Based on the analysis of how teachers implemented the suggested approaches in the *into-the-classroom* lesson. It is likely that this small shift toward student-centred teaching resulted in *teacher-centred progressivist* approaches (Cuban, 2009). This is a hybrid pedagogy, principally teacher-centred, but with features of student-centred teaching, for example, the class might be organised for group-work but the lesson might have a teacher-centred orientation i.e. the teacher demonstrates a method or idea and then students practice using largely routine questions. This I discussed earlier in the chapter in relation to how Imran implemented the ideas in the PD.

Barry and Imran claimed that in their teaching they were giving students more time before intervening, giving them longer to struggle on problems. This is consistent with the overall principles of the PD. Although both teachers described effects in similar ways, the way in which these perceived changes were enacted were very different. It is this difference that I use here to explore the nature and extent of changes in teachers' practices as a result of participating in the PD.

I begin with the influence of the overall philosophy of the PD on Barry's teaching. In his teaching, it was evident that he had aspired to teach in ways suggested by the PD, at least in the high-attaining class I observed. It was also evident that Barry, of all the teachers I observed, was the most efficacious in the approaches suggested in the PD. Although he appeared to be the teacher most oriented to teaching in a student-centred way, he

acknowledged that he generally taught in a more traditional way. He suggested he included some aspects of problem solving into his teaching prior to the PD, but not to the extent that students had opportunity to undertake extended and collaborative problem-solving tasks. This was also limited to higher attaining classes, where the group already demonstrated a disposition toward more open-ended tasks. He characterized this as follows:

> I was brought up ... What's the word? My teaching practice was mostly when it was starter, main, plenary. That is pretty much how I teach [...] The exercise will be, depending on the group, not like the typical exercise where you sit there and do hundreds of them. I wouldn't dream of doing that, but two or three really straightforward problems then something a bit more wordy. Wordy particularly, or having more of a problem-solving aspect to it—more straightforward.
>
> [With lower attaining groups] I feel like it would be a bit more teacher intensive, and I don't know, I am trying to defend myself a bit here. You know what I am saying [...] particularly with a group where the behaviour can be more challenging. One of the things you are often wanting to do is get them quiet and get them working, isn't it? And the easiest way of doing that is to give them a load of examples that they can do, isn't it? I think most teachers would admit to that (Barry, Barrington, *interview post-lesson 4 observation*).

Barry was an extreme case, by that I mean that of the eight teachers I observed, he was most enthusiastic about the PD. I considered him, as a result of his context and personal characteristics, to be somewhat of an outlier amongst the other teachers I had observed regularly. And yet, Barry described the change in his teaching overall in modest terms, and very much dependant on the character of the group he was teaching. With lower attaining groups he was more circumspect about giving students extended opportunity to work on open-ended problems. Behaviour and classroom management became more important, this then dictated the choice of task and activity and the pattern and structure of the teaching.

In giving students more time to work on and think about problems, and not intervene so soon, he was referring to the high-attaining year 11 group with whom I observed him teach. Teaching was more traditional and teacher-centred with his other groups. He was, though, attempting to embrace, engage with, and implement the ideas and fundamental philosophy of the PD.

So, if Barry was the teacher who had greatest proclivity and personal confidence in the approach and his overall change in practice was relatively modest, what of the teachers who were less confident in the approach? What of the teachers who felt more comfortable with a traditional format? Imran provides a valuable contrast in this respect. He was at the same

school as Barry and taught a similar high-attaining year 11 group. He was, in contrast, more traditional in his approach and less confident in implementing the ideas suggested in the PD (which I highlighted in the Chapter 6 and earlier in this chapter. At the same time he characterized the effect of the PD on his teaching in a very similar way to Barry—as not intervening too soon and allowing students to struggle more

As I have shown in the case study of Imran's implementation of the ideas suggested in the PD (see Chapter 6), what Imran had done was to transform the ideas suggested in the PD into a form and lesson structure which limited opportunity for students to work on open-ended tasks for extended periods. Hence, I characterized Imran's lesson as traditional, in that there were relatively routine problems to solve, but the lesson differed from a more orthodox traditional teacher-centred lesson in that he did not explain or demonstrate methods at the beginning. What was happening then was that the Imran would give out questions that were routine but then make the expectation that they would recall the appropriate method to solve the problem. He did not provide activities and tasks that required students to choose or develop their own methods. I concluded that he wanted to avoid this situation as it might lead to difficulties in the management of the classroom and student behaviour. And by his own volition, he did not feel confident in doing this.

These observations were in lessons that were specifically reserved for observation and the experimentation with teaching problem solving and the ideas suggested in the PD. Therefore, I think it unlikely that, in the case of Imran, teaching in his usual day-to-day lessons changed fundamentally. By that I mean that it was unlikely that he would be including lessons or parts of lessons dedicated to developing problem-solving skills. This is not say that he may have introduced more open-ended questioning, more group-work and other student-centred aspects of the approach suggested in the PD. This would certainly be consistent with the results of the pre- and post questionnaire on practices. What is unlikely is that he was doing more lessons that gave students chance to work on problems over an extended period.

In spite of this, taking both the quantitative and qualitative analysis, teaching overall had changed: it had become more student-centred. I characterize the type of changes as similar to Cuban's (2009) idea of teacher-centred progressivism. Teaching remains predominantly teacher-centred with some features of a student-centred approach.

However, I think it is unlikely that a teacher-centred progressivist approach provides sufficient opportunity for students to develop problem-solving skills. The fundamental requirement is having the time and opportunity to work on a complex problem, that is unfamiliar, and does not necessarily have a unique solution, or the method to use may not be obvious. Indeed, this has been recognised recently. For example, a report for the US Education Department argued the need to develop students' "grit, tenacity and perseverance" in developing effective problem-solving

(Schechtman, DeBarger, Dornsife, Rosier, and Yarnell, 2013). Its specific recommendations included:

- Students need to have opportunity to take on long-term and high-order goals;
- They need a "rigorous and supportive environment in which to help them accomplish goals and develop psychological resources" (Schechtman et al., 2013, p. 77).

This means that there should be a greater proportion of lessons with a fundamentally different orientation—that should feature a student-centred problem-solving approach. Teachers in this study appeared to recognise this too. Yet my conclusion from the analysis of changes in practice was that teachers found it too difficult to implement the suggested approach widely. Furthermore, I provide a theoretical justification for this.

One of the teachers articulated the challenges of developing problem solving more generally. Recalling David's observation in Chapter 7, he described the distance and discontinuity between teacher-centred orthodoxy and the approach suggested in the PD.

> . . . I think it's a big change as well, in terms of the change in the kind of culture behind teaching and it's not something that is going to happen immediately. I think it is important to try and get kids to think for themselves, which is kind of the main thrust of the PD, I suppose. But it is tough really, and especially I think because when you take one of these lessons there is an element of risk-taking, because you don't really know where the lesson is going to go and how long things take. So, I think I have been lucky in terms of having the top set, because I think they are very patient but with a lower-down set the patience isn't necessarily there. So for a normal teacher on a normal teaching day you are faced with, 'shall I take this risk with this lower set or should I not?' The easy way out is just to say, 'I will leave it' (David, *interview post-lesson 4 observation*).

Both David and Barry recognised fundamental changes are needed to implement student-centred problem-solving approaches more widely. This is not the same as incorporating aspects of the suggested approach into teacher-centred teaching. Which has, in the US, been the chagrin of Cuban (2009) with the emergence of teachers "hugging the middle". This characterizes practice which is, at heart, teacher-centred but has some features that are student-centred.

Before discussing this further, I want to integrate this conclusion with the discussion I have had in this chapter so far. So, here I have found a small change in teachers' practices: that teaching has become modestly more student-centred overall. It is likely that these changes would be skewed

toward higher attaining classes and that overall changes could easily be of a teacher-centred progressivist type. In other words lessons feature student-centred elements and it is more likely that these will be evident in classes of high attainers.

In the previous section, I concluded that in most cases teachers had more self-efficacy in teaching using a student-centred problem-solving approach, they were more confident in, knowledgeable about and skilled in the ideas presented in the PD. Yet there is a disparity here with what happened *in practice*. Self-efficacy did not result in changes in practice to the same degree. This I attribute to the context and therefore relates to the discussion at the beginning of this chapter. First, that the PD was not integrated into school-development plans and from this I argued that the teaching approach was not fully coherent with the schools strategic aims. As a result, the schools offered limited support or resourcing for the PD implementation. This would explain, at least in part, why the changes in practice, are relatively modest. Would there have been more school-level integration, it might have been that instead of teacher-centred progressivist forms being presented, teachers may have devoted further lessons or extended periods to problem solving more widely.

The idea of the ubiquity of teacher-centred teaching is also an important consideration here. This I introduced in Chapter 3. The prevalent teaching style involved demonstrating a new method followed by pupil practice (OfSTED, 2013). From a *social learning theory* perspective, where there is no motivation to do otherwise, or that existing behaviours or practices are 'working' then behaviours become routinized and almost automatic (Bandura, 1997) and that teaching becomes heuristically implemented knowledge (Leinhardt, 1988). This is consistent with a traditional teacher-centred approach to teaching mathematics with what Cuban (2009) described as "simple, resilient and efficient solutions" (p. 10-11).

The PD provided models of alternative practice, a student-centred problem-solving model, and the means by which teachers could develop self-efficacy in the approach through mastery and vicarious experience and through verbal persuasion. These elements, on their own, are not sufficient to generate sustained change of the kind required to give all students the chance to develop problem-solving skills.

Social learning theory can be used to explain this using the concept of *reciprocal triadic determinism*. This models the reciprocal relationship between the individual, their behaviour and their social context. Here, although individual teachers may have different levels of self-efficacy (including knowledge and skill) in a new set of behaviours (practice and pedagogy), the social context and the didactic contract limit the extent to which that change can be sustained. The factors that would, and even should, overcome the social constraints are the support and resourcing from the school itself. As I have stressed, in none of the four schools that began the study, was PD well integrated into the schools' development plan.

I now briefly consider the final two elements in my analysis of changes

in teachers' practices. The first are the results in relation to what teachers' found more or less difficult to adopt and the second are the results of the analysis of how teachers changed in the observed lessons. I do this briefly as these aspects confirm my emerging conclusions so far.

In terms of what teachers found more or less difficult to adopt, these results were consistent with what I have presented so far, in terms of change. Teachers found it easier to adopt pedagogic elements; for example, group-work and giving students more time to think before helping or intervening. On the other hand teachers found it difficult to give students time to work on and discuss a more open-ended task for a length of time. This became more of a concern with lower-attaining groups. The biggest concern teachers had was with managing behaviour.

This is entirely consistent with the discussion of teacher-centred progressivism previously. Teachers are understandably concerned that a lesson will be relatively smooth-running, part of which means having students on-task. Presenting tasks that present more challenge and that are open-ended is going to cause problems for low-attaining, low-confidence learners in mathematics. This then encourages teachers to be more conservative and maintain the status quo or follow the 'cultural script' as Stigler and Hiebert (1999) referred to it.

Finally, in my analysis of the lessons observed through the project, these results showed that each lesson I observed had multiple and complex context-specific influences, for example, a non-uniform day. While there was no developmental pattern through the lessons I observed, the analysis revealed how much time teachers devoted to students working on open-ended tasks. The more challenging the task, in general, the less time teachers allowed students to work on the problem. The do not want them to go 'off-task' as a result of not making progress with the problem.

In the final chapter, I summarise the main conclusions and findings, I describe the limitations of this study and present the implications of this research.

Chapter 9

Conclusions and implications

In this final chapter, I summarise the main findings of this research and the limitations. Finally, I present some implications arising from this research.

The effects of context and professional development coherence

In the four schools that were initially involved in this research, the context played an important part in how the PD was used. An external accountability culture administered through the evaluation of schools' examination results and through school inspections had an impact on how the *Bowland Professional Development* was implemented. Although school leaders where supportive of the ideas and aims of the professional development, it was not fully integrated into school-level development in any of the schools.

The implementation in all schools was a department-led initiative. This had an impact on the extent to which the PD was implemented in the schools. Two departments began using the materials as they were designed but their commitment diminished. One department withdrew altogether after the first module. The other department sustained commitment but the head of department focussed on half the teachers in the department—those who were already committed to ideas in the PD.

The overriding conclusion from these four schools was that if the schools had made the professional development more integrated with school strategy and school development plans, the professional development would have been implemented in a more sustained way.

Therefore, professional development design needs to take into account the context and how school leaders might interpret the context, in order that the professional development is implemented in a sustained way. Professional development, in order to be effective needs to be integrated into school development and evaluation plans.

How teachers used the PD

Teachers engaged with the ideas presented in the professional development. The process involved teachers observing elements of suggested pedagogy and practice related to the overall approach proposed in the PD. In sessions, they observed video examples of lessons and also used lesson plans detailing the pedagogic elements and structures in the suggested approach. The engagement process involved teachers identifying aspects of pedagogy and assessing how effective those aspects might be in their classroom with different groups of learners.

In the implementation of the ideas in lessons dedicated to trying out the approach suggested in the PD, teachers used the lesson structures that were suggested but adapted pedagogic elements. One teacher adapted the lesson in order that it was consistent with traditional teacher-centred teaching; reducing the amount time student had to work on open-ended problems collaboratively. This adaptation was a consequence of having low self-efficacy in the approach suggested in the PD.

The aspect of the suggested approach that teachers felt least confident in was allowing students extended periods in which to discuss and collaborate on open-ended problems. A teacher more self-efficacious in the approach suggested in the professional development, spent time organising the composition of student groups and giving each student a specific role. This was to improve the management of the time in which students were free to discuss the problem.

One teacher, at the beginning of their teaching career, made few or no adaptations in the lessons based on the PD approach. This was because they did not have experience to draw on to make assessment about what would or not work.

To explain these results and provide a means with which to generalise to other cases, I used *social learning theory*. Fundamental to this is the prevalence of traditional teacher-centred teaching, which represents an approach to teaching which is effective in terms of managing and controlling student behaviour, output and activity. Teacher-centred approaches are well-rehearsed structures and routines that are sustained through observational processes through generations of teachers. From a *social learning theory* perspective these are routinized behaviours that teachers are self-efficacious in.

The *Bowland PD materials* guide teachers to a more student-centred teaching methodology. From an observational learning viewpoint, teachers observe examples and implement the aspects that they believe they will be successful with. If teachers are not self-efficacious in implementing a period of collaborative group-work, they adapt or modify it to reduce the risk of it going wrong. Or they may not do it at all. They are likely to adapt the lesson to be more traditional and teacher-centred because in this form they have confidence that lesson will be smooth running.

In order to successfully implement new approaches to teaching, for ex-

ample, reform-oriented or student-centred practices, it is necessary teachers are offered models of the practice, a means for teachers to engage with the model and that teachers are sufficiently self-efficacious in the approach to implement the alternative or incorporate it into their existing practice.

The problem is that if the proposed alternative is considerably different or teachers are not confident enacting it, then they will adapt it to an approach that they are comfortable with, taking with it surface features of the suggested approach. This classic phenomena has been illustrated elsewhere (Cohen, 1990; Cuban, 2009), but accounted for in this research.

How teachers changed

The professional development had an impact on teachers' self-efficacy. The overall effect was that teachers who participated in the professional development were more confident in teaching using the suggested approach as a result of the PD programme. Although, in some cases, teachers' self-efficacy in teaching using the suggested approach had not increased, this was attributable to not having a positive experience in the lessons where they tried out the ideas suggested in the PD. The sources of self-efficacy were a combination of having successful experience when teachers tried out the ideas with one of their classes, vicariously from observing video examples of lessons in the PD sessions and from verbal persuasion from colleagues. These are the three sources of self-efficacy as proposed by Bandura (1997).

In addition to teachers' self-efficacy, teachers claimed their practices had changed. They suggested that their teaching in all lessons had become more student-centred. The particular aspects that they said that they were doing more of was to give students more time to work on problems before they stepped in helped them, including more opportunities for more collaborative work and also using more open-ended questioning. However, I conclude by accepting there was change but the nature of change was toward a student-centred progressivist model of teaching (Cuban, 2009). This means that teaching remains, principally, teacher-centred with some surface features of student-centred practice, for example, group-work. My concern—and this needs further research—is this kind of hybrid practice does not provide the students the chance to genuinely develop their problem-solving skills.

While my overall conclusions might appear quite negative in respect to the professional development under investigation, this study has revealed it did have an effect. It had an effect on teacher self-efficacy and on teacher practices. The high quality of the design of the PD combined with this impact evidence means that the PD materials have considerable value. But what this research has revealed, most of all, is a new way of theorizing professional learning by using *social learning theory* and its components: *observational learning*, *reciprocal determinism* and *self-efficacy*. In this research, I believe I have pioneered its application in the study of mathe-

matics teachers' professional learning. From which I will be doing further study to refine and develop the theory and the evaluation methodology I have used here but in different contexts.

Limitations

The effects of context and the issue of coherence that I identified in this research is a product of the more exploratory aspects of the research. I have made the claim that the PD would have been implemented more effectively and in a more sustained way if the professional development had been integrated into school-level processes. In this research, I did not consider the perspectives of school leaders, except in one school where they had withdrawn from the project. I suggest, therefore, that further research is needed to explore whole-school issues and perspectives in relation to subject-specific professional development.

The way in which teachers used the PD was based on intensity sampling of case studies within the overall project. The first part of this was the analysis of a discussion between one group of teachers observing an example lesson. The second part involved case studies of three teachers from different schools. The results then are specific to these cases and contexts. However, I chose to use an analytic generalisation approach and use theory as the means by which I generalise the findings from these embedded cases. In order for this to be effective, I considered alternative explanation and rival theory. In my analysis in the results chapters, I discussed and considered alternative explanations. I also considered rival theory, by considering an alternative theoretical perspective, that of teachers' beliefs. What has to be borne in mind in reading the findings in this conclusion is the possibility of further alternative explanation or rival theory.

Yet overall, I have attempted a novel approach in this research and as such I have to concede that by attempting to develop a new approach, some areas of the research are indeed tentative. This research is, in part an exploratory and imaginative engagement with theory. My motivation for this was the lack of theory in the aspect of professional development I was interested in here. I believe this study has revealed some interesting directions and areas that I and others could research in the future.

This research did not look at the effects of the PD on student attainment. However, the use of self-efficacy provides some indication of an effect on student attainment indirectly. Teacher self-efficacy has been linked to student achievement (Armor, Conroy-Oseguera, Cox, King, McDonnell, Pascal, Pauly, and Zellman, 1976; Ashton and Webb, 1986; Moore and Esselman, 1992; Ross, 1992). Although, it was not possible to determine across the three schools, whether there was an effect on student achievement, there was some indication of improvement, if one is to take the changes in teacher self-efficacy as evidence for this. However, this is tentative and further research is needed to assess the extent to which teacher

self-efficacy correlates with student attainment. There is a growing body of research that indicates teacher self-efficacy as one of the key teacher variables that is related to student attainment (for example, Klassen et al., 2011). This is will be a worthwhile area to explore both quantitatively and qualitatively in the future.

A final but nonetheless important limitation is the issue of low-attaining learners. I acknowledge the ability group or 'set' that a student is placed in is closely related to the socio-economic status and background of the student. I am acutely aware that the consequence of this research design has been to foreground the needs of high-attainers and so to foreground the more privileged within state schools. This, rather than being a conscious act of discrimination, arose from the practical needs of this particular research and the compromises as a result of the interests of the funders. Who, it has to be said, did not necessarily set out to discriminate against groups of learners. In order to offer some redress, I am working on a future project looking into mathematics pedagogy in low-attaining sets.

Implications

This research has highlighted a new approach to understanding mathematics teachers' professional learning. This is based on social learning theory. What is most important is that this theoretical approach permits an integrated and complimentary analysis of individual characteristics and learning processes with the analysis of social and cultural context.

The design of the PD used a professional learning model based on mathematics teachers' beliefs about the teaching and learning mathematics. From this perspective, the practices teachers implement in their classrooms are influenced by their beliefs about effective teaching and learning (Ernest, 1989; Schoenfeld, 2010; Swan, 2006a; Thompson, 1984). Thus, a teacher who believes that effective learning is supported by transmission or a behaviourist theory based learning approach will have a proclivity toward traditional teacher-centred teaching (Ernest, 1989). Although Ernest (1989) and Thompson (1984) acknowledged that 'beliefs' were likely to be influenced by the social setting. If a teacher believed a constructivist learning theory approach was the most effective approach to learning mathematics, this might not be manifest because of social expectations in the school.

This research unveils a more fine-grained theorization of professional learning. I accept that while teacher beliefs or orientations toward learning theories might be important, the judgements teachers make about the way they teach are made at a more pragmatic level. I propose, based on this research, that *social learning theory* provides a more effective means of theorising professional learning, in this context, but I also conjecture that it is useful beyond these cases and contexts.

Social learning theory (also referred to as social cognitive theory) has three components: *observational learning*, *reciprocal determinism* and *self-*

efficacy. Observational learning, from a social learning theory, frames learning processes as observing model behaviour, the retention of symbolic representations of the observed behaviour, the production of behaviour and action and motivational processes that guide the choice of symbolic models and therefore behaviour.

Reciprocal determinism is organising meta-theory in *social learning theory*. It connects the person with their environment and the behaviour in a reciprocal triadic arrangement. This summarises the link between the individual cognition and the effects of the social setting.

Self-efficacy is a forward-oriented belief in an individual's ability to bring about a level of outcome in a domain. Teaching self-efficacy is the belief a teacher has in their ability to support students in effective learning.

This research provides a vehicle to demonstrate a *social learning theory* analysis. Arising from this I propose the following conditions for effective professional learning:

- The professional development needs to *cohere* and align with the external contextual factors. Importantly professional develop needs to be integrated into school-level development and evaluation plans.
- The professional development must include **models** of the suggested approaches, pedagogy and practices.
- Their needs to be a **professional development process** for teachers to engage with the modelled approach.
- Teachers need to be able to develop **self-efficacy** in the suggested approach as part of the PD

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Appendices

Post-questionnaire responses - raw data and preliminary processing.

			Amy	Matt	Lynne	Mary	Cath	Jenny	Kelly	Imran	David	Nigel	Jane	Lydia	Tony	Peter	Anne	Cheryl	Deborah	Adrian
			Boxton	Norman Fletcher	Barrington	Boxton	Norman Fletcher	Norman Fletcher	Tuxford Academy	Barrington	Boxton	Boxton	Boxton	Norman Fletcher	Boxton	Norman Fletcher	Norman Fletcher	Barrington	Barrington	Boxton
	PRACTICES QUESTIONNAIRE																			
1	Students work through exercises.	T	About half the time	About half the time	About half the time	Occasionally	Most of the time	About half the time	About half the time	Almost always	Most of the time	About half the time	About half the time	Most of the time	About half the time	About half the time	Most of the time	About half the time	Occasionally	Most of the time
2	Students work on their own, consulting a neighbour from time to time.	T	Occasionally	Most of the time	About half the time	Almost never	About half the time	About half the time	Occasionally	Most of the time	Almost always	About half the time	About half the time	Most of the time	Occasionally	Almost never	About half the time	Occasionally	Occasionally	About half the time
3	Students use only the methods I teach them.	T	Most of the time	Occasionally	Most of the time	Most of the time	Most of the time	Occasionally	Occasionally	Most of the time	About half the time	Most of the time	About half the time	Most of the time	Most of the time	Most of the time	Most of the time	About half the time	Occasionally	Most of the time
4	Students start with easy questions and work up to harder questions.	T	Occasionally	About half the time	Most of the time	Most of the time	Occasionally	About half the time	About half the time	Almost always	Occasionally	Occasionally	About half the time	Most of the time	Most of the time	About half the time	Most of the time	Most of the time	Occasionally	Most of the time
5	Students choose which questions they tackle.	S	Most of the time	About half the time	Occasionally	Occasionally	Most of the time	About half the time	About half the time	Occasionally	Occasionally	About half the time	About half the time	About half the time	Almost never	Most of the time	Most of the time	Most of the time	Most of the time	About half the time
6	I encourage learners to work more slowly.	S	Occasionally	Occasionally	Almost never	Occasionally	Almost never	Almost never	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Almost never	About half the time	Almost never	Almost never	Occasionally	Occasionally	Occasionally
7	Students compare different methods for doing questions.	S	Most of the time	Occasionally	Occasionally	Occasionally	About half the time	Occasionally	Most of the time	About half the time	Occasionally	Occasionally	About half the time	About half the time	Occasionally	Occasionally	About half the time	Occasionally	Most of the time	Most of the time
8	I teach each topic from the beginning assuming they know nothing.	T	Occasionally	About half the time	Almost never	About half the time	Almost never	Occasionally	Almost never	Most of the time	About half the time	Most of the time	Most of the time	Almost never	Almost never	Almost never	Almost never	Almost never	Almost never	Almost never
9	I teach the whole class at once.	T	About half the time	About half the time	Most of the time	Most of the time	Most of the time	Most of the time	About half the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Occasionally	Most of the time	Most of the time
10	I try to cover everything in a topic.	T	About half the time	Most of the time	Most of the time	Most of the time	Almost always	About half the time	Occasionally	Almost always	Most of the time	Most of the time	About half the time	Most of the time	Almost always	Almost always	Almost always	Most of the time	About half the time	Almost always
11	I draw links between topics and move back and forth between topics.	S	About half the time	Most of the time	Most of the time	About half the time	About half the time	Occasionally	Almost always	Almost always	Most of the time	Most of the time	Most of the time	Most of the time	Almost always	Almost always	Almost always	Most of the time	Most of the time	Almost always
12	Students work collaboratively in small groups.	S	Most of the time	About half the time	About half the time	Most of the time	Occasionally	Occasionally	About half the time	About half the time	Occasionally	About half the time	About half the time	Occasionally	Most of the time	Most of the time	Occasionally	Occasionally	Occasionally	Almost always
13	I avoid students making mistakes by explaining things carefully first.	T	Most of the time	About half the time	Most of the time	About half the time	About half the time	About half the time	Most of the time	Most of the time	Occasionally	Most of the time	About half the time	Most of the time	Most of the time	Almost never	About half the time	About half the time	Occasionally	Almost always
14	I tend to follow the textbook closely.	T	Almost never	Occasionally	Almost never	Almost never	Almost never	Almost never	Almost never	About half the time	Almost never	Almost never	Occasionally	About half the time	Occasionally	Occasionally	Almost never	Occasionally	Almost never	Occasionally
15	Students discuss their ideas.	S	Most of the time	Most of the time	Most of the time	Almost always	Most of the time	Most of the time	Almost always	About half the time	Almost always	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time
16	Students work collaboratively in pairs.	S	Almost always	Most of the time	About half the time	Most of the time	Almost always	Occasionally	Most of the time	Most of the time	Most of the time	About half the time	About half the time	Occasionally	Almost always	Almost always	Most of the time	Most of the time	Most of the time	Most of the time
17	Students invent their own methods.	S	About half the time	Most of the time	Occasionally	Occasionally	Occasionally	Occasionally	About half the time	About half the time	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	About half the time	About half the time
18	Students work on substantial tasks that can be worked on at different levels.	S	About half the time	Occasionally	Occasionally	Occasionally	About half the time	Occasionally	About half the time	Most of the time	Occasionally	Occasionally	About half the time	Occasionally	Occasionally	Occasionally	Most of the time	About half the time	Occasionally	Occasionally
19	I tell learners which questions to tackle.	T	About half the time	About half the time	Most of the time	Almost always	Most of the time	About half the time	Occasionally	Most of the time	About half the time	Occasionally	About half the time	About half the time	Most of the time	About half the time	About half the time	Occasionally	About half the time	Almost always
20	I encourage students to work more quickly.	T	Occasionally	Most of the time	Most of the time	Occasionally	Most of the time	Almost never	Most of the time	About half the time	Most of the time	Occasionally	About half the time	About half the time	Occasionally	Most of the time	About half the time	Occasionally	Occasionally	About half the time
21	I go through one method for doing each question.	T	Occasionally	Almost never	Almost never	Almost always	Almost never	Occasionally	Almost never	Most of the time	Occasionally	Occasionally	About half the time	Occasionally	Most of the time	About half the time	Occasionally	Occasionally	Occasionally	Occasionally
22	I find out which parts students already understand and don't teach those parts.	S	Most of the time	About half the time	Most of the time	Most of the time	Most of the time	About half the time	About half the time	Occasionally	About half the time	About half the time	Occasionally	About half the time	Almost never	Most of the time	Almost always	Most of the time	Most of the time	Most of the time
23	I teach each student differently according to individual needs.	S	Most of the time	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	Almost always	Almost never	About half the time	Occasionally	Occasionally	Occasionally	Most of the time	Most of the time	Occasionally	About half the time	Occasionally	Almost always
24	I cover only the important ideas in a topic.	S	Occasionally	Occasionally	Occasionally	Almost never	Occasionally	Almost never	Almost never	Most of the time	Occasionally	Occasionally	Occasionally	Occasionally	Almost never	Most of the time	About half the time	Occasionally	About half the time	Occasionally
25	I teach each topic separately	T	About half the time	Occasionally	Almost never	Most of the time	About half the time	About half the time	Occasionally	Most of the time	About half the time	About half the time	Occasionally	About half the time	Occasionally	Most of the time	About half the time	Occasionally	Occasionally	Occasionally
26	I know exactly what maths the lesson will contain.	T	About half the time	Occasionally	Most of the time	Almost always	Most of the time	Most of the time	About half the time	Almost always	Most of the time	Most of the time	About half the time	Almost always	About half the time	About half the time	About half the time	About half the time	Most of the time	Most of the time
27	I encourage students to discuss mistakes they make.	S	Most of the time	Most of the time	Most of the time	Most of the time	Almost always	About half the time	Almost always	About half the time	Most of the time	Most of the time	Most of the time	Most of the time	Almost always	Almost always	Most of the time	Most of the time	Most of the time	Almost always
28	I jump between topics as the need arises.	S	Most of the time	About half the time	Most of the time	Most of the time	Most of the time	Occasionally	Almost always	About half the time	Most of the time	About half the time	About half the time	Most of the time	Most of the time	Almost always	Most of the time	Most of the time	Most of the time	Most of the time
	T-centred score		**71**	**80**	**87**	**90**	**83**	**90**	**66**	**99**	**86**	**87**	**86**	**94**	**85**	**74**	**80**	**75**	**70**	**80**
	TEACHER SELF-EFFICACY QUESTIONNAIRE	Efficacy factor																		
1	Controlling disruptive behaviour in the classroom.	CM	8	9	9	8	7	7	8	9	9	9	7	7	8	7	8	8	8	8
2	Motivating students who show low interest in school work.	SE	6	6	8	7	7	6	7	7	8	8	7	6	8	6	7	5	7	7
3	Getting students to believe they can do well in school work.	SE	7	6	8	7	8	7	7	9	7	8	7	7	8	7	8	7	8	8
4	Helping your students value learning.	SE	6	5	8	5	7	6	7	9	8	8	7	6	8	8	8	6	7	7
5	Crafting good questions for your students.	IS	7	6	9	5	7	6	7	8	7	8	7	7	8	7	9	7	7	9
6	Getting children to follow classroom rules.	CM	7	9	9	8	7	7	7	8	9	9	7	7	8	7	7	8	8	7
7	Calming a student who is disruptive or noisy.	CM	7	9	9	6	7	6	8	6	8	9	7	6	8	8	9	7	8	7
8	Establishing a classroom management system with each class.	CM	7	9	9	8	7	8	8	7	8	9	7	6	8	7	7	8	8	8
9	Using a variety of assessment strategies.	IS	9	8	9	7	7	8	8	8	7	8	7	7	8	9	9	8	8	8
10	Providing an alternative explanation or example when students are confused.	IS	7	9	9	7	8	7	8	9	7	9	7	8	8	9	9	8	8	9
11	Assisting families in helping their children do well in school.	SE	6	9	7	3	3	3	6	8	6	6	5	7	6	4	6	7	7	7
12	Implementing alternative strategies in your classroom.	IS	7	8	8	5	8	7	7	8	7	7	7	6	8	6	8	8	8	7
	Efficacy for classroom management		**29**	**36**	**36**	**30**	**28**	**28**	**31**	**30**	**34**	**36**	**28**	**26**	**32**	**29**	**31**	**31**	**32**	**30**
	Efficacy for instructional strategies		**30**	**31**	**35**	**24**	**30**	**28**	**30**	**33**	**28**	**32**	**28**	**28**	**32**	**31**	**35**	**31**	**31**	**33**
	Efficacy for student engagement		**25**	**26**	**31**	**22**	**25**	**22**	**27**	**33**	**29**	**30**	**26**	**26**	**30**	**25**	**29**	**25**	**29**	**29**
	TEACHING PROBLEM SOLVING EFFICACY QUESTIONNAIRE																			
1	Setting out the problem so that students can start working without detailed guidance about procedures.		6	6	7	7	7	8	7	7	7	6	7	7	8	6	9	6	7	7
2	Getting students to reflect individually on the problem and consider their options for strategy.		5	5	7	7	7	7	7	7	7	5	7	7	7	7	8	6	7	7
3	Allowing students to choose what resources to use (PCs, calculators, protractors, compasses and other tools and materials).		6	6	7	3	5	6	8	8	7	5	7	7	7	9	9	6	7	6
4	Helping students organise themselves into effective groups.		5	7	7	9	5	6	7	8	5	7	8	7	7	6	8	5	7	5
5	Facilitating student groups discussing the problem together.		5	7	7	8	6	6	8	8	8	8	7	7	8	8	7	7	8	6
6	Getting students to build on and challenge one another's ideas constructively.		5	6	7	6	7	5	8	8	6	6	7	6	6	7	8	6	7	7
7	Keeping talk mathematical rather than just idle chatter.		5	5	7	7	6	6	8	8	7	7	7	7	7	6	8	6	7	4
8	Ensuring all members of a group contribute.		5	5	7	7	6	7	8	7	7	7	7	7	6	8	7	5	6	4
9	Giving guidance where groups are not working well together.		6	4	7	7	6	7	8	6	6	8	6	7	8	6	8	7	7	5
10	Getting students to behave responsibly and appropriately when working on open-ended problems together.		6	7	8	7	7	7	8	7	8	7	7	6	7	8	8	7	7	6
11	Getting students to use mathematical skills effectively to solve problems.		6	7	7	7	7	7	8	6	7	6	7	7	7	8	8	7	7	7
12	Providing appropriate levels of assistance to struggling students.		6	8	7	8	7	7	8	6	6	6	7	8	8	8	8	8	8	6
13	crafting good questions that support students' problem-solving.		7	9	7	7	6	7	8	6	7	6	7	8	7	7	9	8	7	8
14	Allowing students to choose what maths to use.		6	9	7	4	7	8	8	5	7	6	7	7	8	8	9	8	7	7
15	Developing mathematical skills and knowledge in this kind of lesson.		6	7	7	6	7	7	8	6	7	6	7	7	7	8	8	7	7	6
16	Encouraging students to present their findings to the rest of the class.		4	7	7	7	8	8	8	5	7	7	7	7	7	9	9	7	7	8
17	Getting students to evaluate their progress on solutions and identify next steps.		5	6	7	5	8	7	8	6	7	6	7	6	7	7	8	6	7	8
18	Providing formative assessment of students' problem solving.		6	5	7	4	8	5	7	8	7	5	7	7	7	7	8	6	6	7
19	Using ICT (e.g. PCs) to support students' problem solving.		5	9	7	4	7	6	7	8	4	5	7	5	5	7	8	6	7	7
20	Ensuring a definite conclusion to the lesson rather than just "stop there and pack up".		5	9	7	7	8	7	8	6	9	6	6	5	7	9	6	6	8	8
	Teaching problem solving efficacy score		**110**	**134**	**141**	**127**	**135**	**134**	**155**	**136**	**136**	**125**	**139**	**135**	**141**	**149**	**161**	**130**	**141**	**129**

The above table is a coded table of the categorical ordinal table above left. For teacher-centred (T) practices , see column C, each response is coded:

1-Almost never
2-Occasionally
3-About half the time
4-Most of the time
5-Almost always

Items that are student-centred (S), see column C, the responses are reverse coded:

1-Almost always
2-Most of the time
3-About half the time
4-Occasionally
5-Almost never

All efficacy scores were on a scale of 1-9.
1-Cannot do at all
3-Can do a little
5-Moderatley can do
7-Can do quite a lot
9-Certain can do

Teaching efficacy factors each range from 4-36
Teaching problem solving efficacy score ranges from 20-180

Pre-questionnaire responses - raw data and preliminary processing.

		Student- or teacher centred	Ashleigh Boxton	Andrew Norman Fletcher	Lisa Barrington	Ruth Boxton	Katrina Norman Fletcher	Janet Norman Fletcher	Kelly Boxton	Imran Barrington	Michael Boxton	Neil Boxton	Jenny Boxton	Sue Norman Fletcher	Allan Boxton	Phil Norman Fletcher	Andrea Norman Fletcher	Caroline Barrington	Alison Barrington	Chris Boxton
	PRACTICES QUESTIONNAIRE																			
1	Students work through exercises.	T	Most of the time	About half the time	About half the time	About half the time	Occasionally	About half the time	About half the time	Most of the time	About half the time	About half the time	About half the time	Most of the time	About half the time	Most of the time	About half the time	Most of the time	Occasionally	Most of the time
2	Students work on their own, consulting a neighbour from time to time.	T	Most of the time	About half the time	About half the time	About half the time	Occasionally	Occasionally	Most of the time	About half the time	Almost never	Occasionally	Most of the time	Most of the time	Most of the time	Almost never	About half the time	About half the time	Occasionally	About half the time
3	Students use only the methods I teach them.	T	About half the time	Occasionally	Most of the time	Most of the time	About half the time	Occasionally	Almost never	Most of the time	Most of the time	Most of the time	Most of the time	About half the time	Most of the time	About half the time	About half the time	Most of the time	Occasionally	Occasionally
4	Students start with easy questions and work up to harder questions.	T	Most of the time	Most of the time	About half the time	Almost always	Occasionally	About half the time	Most of the time	Most of the time	Almost never	Most of the time	Most of the time	Most of the time	Most of the time	About half the time	Most of the time	Most of the time	Occasionally	About half the time
5	Students choose which questions they tackle.	S	Almost always	Occasionally	Occasionally	Occasionally	Most of the time	About half the time	About half the time	Almost never	Occasionally	Occasionally	Occasionally	Most of the time	Occasionally	Most of the time	Occasionally	Occasionally	Occasionally	Almost never
6	I encourage learners to work more slowly.	S	Almost never	Occasionally	Occasionally	Occasionally	Almost never	Occasionally	Almost never	About half the time	Almost never	About half the time	Occasionally	Almost never	Occasionally	About half the time	Almost never	Occasionally	Almost never	Almost never
7	Students compare different methods for doing questions.	S	About half the time	About half the time	Occasionally	Occasionally	About half the time	About half the time	Most of the time	Occasionally	About half the time	Almost never	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Most of the time
8	I teach each topic from the beginning assuming they know nothing.	T	Almost never	Most of the time	Almost never	Occasionally	Almost never	Occasionally	Almost never	Occasionally	Occasionally	Most of the time	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	Almost never	Almost never	Occasionally
9	I teach the whole class at once.	T	Occasionally	Most of the time	Almost always	Most of the time	Most of the time	Most of the time	About half the time	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time	Almost always	Most of the time	Most of the time	About half the time	Most of the time	Most of the time
10	I try to cover everything in a topic.	T	About half the time	Most of the time	Most of the time	Most of the time	Most of the time	About half the time	Most of the time	Almost always	Almost always	Almost always	About half the time	Most of the time	Most of the time	Almost always	About half the time	Almost always	Occasionally	Most of the time
11	I draw links between topics and move back and forth between topics.	S	About half the time	About half the time	Most of the time	Occasionally	Most of the time	Occasionally	Most of the time	Most of the time	About half the time	Almost always	About half the time	Most of the time	Most of the time	Almost always	About half the time	Most of the time	Most of the time	Almost always
12	Students work collaboratively in small groups.	S	Occasionally	About half the time	Occasionally	About half the time	Occasionally	Occasionally	About half the time	About half the time	Occasionally	About half the time	Occasionally	Occasionally	Occasionally	About half the time	Occasionally	About half the time	Occasionally	Occasionally
13	I avoid students making mistakes by explaining things carefully first.	T	Most of the time	About half the time	Occasionally	Almost always	Occasionally	About half the time	Most of the time	About half the time	Occasionally	Almost always	About half the time	Most of the time	Occasionally	Almost never	About half the time	About half the time	About half the time	Almost always
14	I tend to follow the textbook closely.	T	Occasionally	Occasionally	Almost never	Occasionally	Almost never	Occasionally	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	About half the time	Occasionally	About half the time	Occasionally	Almost never	Almost never	Occasionally
15	Students discuss their ideas.	S	Most of the time	About half the time	Most of the time	About half the time	Almost always	About half the time	Almost always	Occasionally	Most of the time	About half the time	Most of the time	Almost always	Most of the time	Almost always	Occasionally	About half the time	About half the time	Almost always
16	Students work collaboratively in pairs.	S	Most of the time	Most of the time	About half the time	Most of the time	Almost always	Occasionally	Most of the time	About half the time	Almost always	Most of the time	About half the time	About half the time	Almost always	Almost always	About half the time	About half the time	Occasionally	Almost always
17	Students invent their own methods.	S	About half the time	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Almost never	Occasionally	Occasionally	Most of the time
18	Students work on substantial tasks that can be worked on at different levels.	S	About half the time	Occasionally	Occasionally	Almost never	About half the time	Occasionally	Occasionally	About half the time	Occasionally	Occasionally	Occasionally	Occasionally	Almost never	Almost never	About half the time	About half the time	Occasionally	Occasionally
19	I tell learners which questions to tackle.	T	Occasionally	Occasionally	Most of the time	Almost always	About half the time	Occasionally	About half the time	Most of the time	Most of the time	Most of the time	About half the time	About half the time	Most of the time	About half the time	About half the time	Most of the time	Most of the time	Almost always
20	I encourage students to work more quickly.	T	About half the time	Almost always	Occasionally	Occasionally	About half the time	Occasionally	About half the time	Occasionally	Most of the time	About half the time	Occasionally	About half the time	Most of the time	About half the time	Occasionally	Occasionally	About half the time	About half the time
21	I go through one method for doing each question.	T	Occasionally	Occasionally	Almost never	About half the time	Almost never	Most of the time	Almost never	Occasionally	Occasionally	Almost never	Occasionally	Occasionally	Most of the time	Occasionally	About half the time	Occasionally	Occasionally	Occasionally
22	I find out which parts students already understand and don't teach those parts.	S	Most of the time	Occasionally	Most of the time	Most of the time	Almost always	About half the time	Most of the time	Occasionally	Most of the time	Most of the time	About half the time	Most of the time	Almost never	Most of the time	Most of the time	Most of the time	Most of the time	Most of the time
23	I teach each student differently according to individual needs.	S	About half the time	Occasionally	Most of the time	Almost never	Most of the time	Occasionally	Almost always	Most of the time	About half the time	About half the time	Occasionally	Occasionally	Most of the time	About half the time	Occasionally	Occasionally	Occasionally	Almost always
24	I cover only the important ideas in a topic.	S	Occasionally	Almost never	Occasionally	Occasionally	About half the time	Occasionally	Almost never	Most of the time	Almost never	Occasionally	Occasionally	About half the time	Almost never	Almost never	Occasionally	Almost never	Almost never	Occasionally
25	I teach each topic separately	T	About half the time	About half the time	Almost never	Most of the time	Occasionally	Most of the time	Almost never	Occasionally	Occasionally	Most of the time	Occasionally	Most of the time	Almost never	Most of the time	About half the time	Occasionally	Occasionally	About half the time
26	I know exactly what maths the lesson will contain.	T	Most of the time	Occasionally	Most of the time	Almost always	About half the time	Most of the time	Most of the time	Almost always	Occasionally	Almost always	About half the time	Most of the time	About half the time	Occasionally	Most of the time	Occasionally	Most of the time	Most of the time
27	I encourage students to discuss mistakes they make.	S	Most of the time	About half the time	Most of the time	Occasionally	Almost always	Most of the time	Almost always	Occasionally	Most of the time	Almost always	Most of the time	About half the time	Almost always	Almost always	About half the time	Most of the time	Most of the time	Almost always
28	I jump between topics as the need arises.	S	Most of the time	Most of the time	Most of the time	About half the time	Most of the time	Occasionally	Most of the time	About half the time	Almost always	Most of the time	Occasionally	About half the time	Most of the time	Most of the time	Occasionally	Occasionally	Most of the time	Most of the time
	T-centred score		80	90	81	102	67	90	76	92	81	91	90	92	92	77	96	87	84	81

		Efficacy factor																		
	TEACHER SELF-EFFICACY QUESTIONNAIRE																			
1	Controlling disruptive behaviour in the classroom.	CM	7	8	8	7	6	8	9	9	9	9	7	7	8	4	7	6	7	7
2	Motivating students who show low interest in school work.	SE	7	6	7	5	7	7	8	9	8	8	7	7	8	8	5	5	6	5
3	Getting students to believe they can do well in school work.	SE	7	7	8	5	7	7	7	9	7	8	7	7	8	8	7	5	7	6
4	Helping your students value learning.	SE	6	6	8	5	6	6	8	8	8	8	7	6	7	7	6	4	6	6
5	Crafting good questions for your students.	IS	7	5	9	5	6	6	7	8	7	8	7	6	7	2	6	6	7	8
6	Getting children to follow classroom rules.	CM	7	7	8	7	7	7	8	9	8	8	7	6	8	5	6	6	7	7
7	Calming a student who is disruptive or noisy.	CM	7	8	8	5	7	7	8	8	7	9	7	6	8	8	8	5	7	7
8	Establishing a classroom management system with each class.	CM	7	8	9	8	8	8	9	9	8	9	7	7	8	5	8	5	7	7
9	Using a variety of assessment strategies.	IS	8	9	9	7	5	8	9	8	7	8	6	8	8	7	8	6	7	5
10	Providing an alternative explanation or example when students are confused.	IS	6	9	9	7	7	8	9	8	7	8	7	9	8	9	9	7	8	6
11	Assisting families in helping their children do well in school.	SE	5	6	6	3	6	5	6	7	7	7	7	8	7	3	6	4	5	6
12	Implementing alternative strategies in your classroom.	IS	7	8	8	5	8	6	6	8	7	8	6	7	7	5	8	6	7	8
	Efficacy for classroom management		**28**	**31**	**33**	**27**	**28**	**30**	**34**	**35**	**32**	**35**	**28**	**26**	**32**	**22**	**29**	**22**	**28**	**28**
	Efficacy for instructional strategies		**28**	**31**	**35**	**24**	**26**	**28**	**31**	**32**	**28**	**32**	**26**	**30**	**30**	**23**	**31**	**25**	**29**	**27**
	Efficacy for student engagement		**25**	**25**	**29**	**18**	**26**	**25**	**29**	**33**	**30**	**31**	**28**	**28**	**30**	**26**	**24**	**18**	**24**	**23**
	TEACHING PROBLEM SOLVING EFFICACY QUESTIONNAIRE																			
1	Setting out the problem so that students can start working without detailed guidance about procedures.		4	4	7	3	5	5	6	5	5	5	7	6	3	3	7	5	7	7
2	Getting students to reflect individually on the problem and consider their options for strategy.		4	4	7	3	6	5	7	6	6	6	7	6	7	4	6	5	7	7
3	Allowing students to choose what resources to use (PCs, calculators, protractors, compasses and other tools and materials).		5	5	7	2	7	3	6	8	6	5	7	7	3	4	8	6	6	4
4	Helping students organise themselves into effective groups.		4	5	6	6	5	5	7	8	4	7	6	6	6	7	7	4	6	3
5	Facilitating student groups discussing the problem together.		6	5	7	5	5	6	7	7	6	7	6	7	8	8	6	5	6	5
6	Getting students to build on and challenge one another's ideas constructively.		5	7	7	3	4	6	5	6	6	6	5	6	6	5	3	6	5	5	7
7	Keeping talk mathematical rather than just idle chatter.		5	8	7	5	5	6	5	8	5	7	7	6	4	9	6	4	7	4
8	Ensuring all members of a group contribute.		3	6	7	6	6	6	4	6	3	7	6	7	3	8	6	4	6	6
9	Giving guidance where groups are not working well together.		5	6	7	6	6	6	6	7	6	8	7	8	8	7	6	6	6	6
10	Getting students to behave responsibly and appropriately when working on open-ended problems together.		5	7	7	6	7	5	7	8	6	7	7	8	7	5	6	4	7	4
11	Getting students to use mathematical skills effectively to solve problems.		5	5	7	6	6	5	7	8	7	6	7	8	6	7	7	5	6	6
12	Providing appropriate levels of assistance to struggling students.		7	5	7	7	7	7	7	8	7	6	7	8	5	8	8	6	7	7
13	crafting good questions that support students' problem-solving.		6	6	7	2	5	7	7	8	7	6	7	7	6	4	8	7	7	7
14	Allowing students to choose what maths to use.		6	6	7	2	6	7	7	7	7	6	7	7	7	6	9	6	6	6
15	Developing mathematical skills and knowledge in this kind of lesson.		5	5	6	5	5	7	7	8	6	6	7	7	6	8	8	6	6	5
16	Encouraging students to present their findings to the rest of the class.		5	7	8	6	7	7	6	7	6	7	7	8	7	4	9	6	7	6
17	Getting students to evaluate their progress on solutions and identify next steps.		5	5	6	3	6	6	6	7	6	5	7	8	6	5	7	6	6	6
18	Providing formative assessment of students' problem solving.		6	6	7	2	5	7	5	8	5	5	7	7	4	7	6	6	5	6
19	Using ICT (e.g. PCs) to support students' problem solving.		5	7	7	2	4	5	5	7	5	4	7	5	3	9	7	5	7	8
20	Ensuring a definite conclusion to the lesson rather than just "stop there and pack up".		6	8	7	5	7	6	6	6	7	5	6	5	7	7	6	4	7	8
	Teaching problem solving efficacy score		**102**	**117**	**138**	**85**	**114**	**117**	**123**	**143**	**116**	**120**	**135**	**137**	**111**	**123**	**139**	**105**	**127**	**118**

The above table is a coded table of the categorical ordinal table above left. For teacher-centred (T) practices , see column C, each response is coded:

1-Almost never
2-Occasionally
3-About half the time
4-Most of the time
5-Almost always

Items that are student-centred (S), see column C, the responses are reverse coded:

1-Almost always
2-Most of the time
3-About half the time
4-Occasionally
5-Almost never

All efficacy scores were on a scale of 1-9.
1-Cannot do at all
3-Can do a little
5-Moderatley can do
7-Can do quite a lot
9-Certain can do

Teaching efficacy factors each range from 4-36
Teaching problem solving efficacy score ranges from 20-180